AD-A101 628 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH F/G 9/2
THE DESIGN AND IMPLEMENTATION OF A TRANSLATOR FOR ARITHMETIC AN--ETC(U)
1980 M L BISHOP
UNCLASSIFIED AFIT-CI-80-61R NL

1 OF 1
AD A
101628

END
DATE
FILMED
8-81
DTIC

UNCLASS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AFIT-CI-

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 80-61R	2. GOVT ACCESSION NO: AD-A101 628
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): The Design and Implementation of a Translator for Arithmetic and Boolean Expressions.	5. TYPE OF REPORT & PERIOD COVERED: THESIS/DISSERTATION REPORT
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Marin L. Bishop	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: AFIT STUDENT AT: Texas A&M University	10. PROGRAM ELEMENT PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: AFIT/NR WPAFB OH 45433	12. REPORT DATE: 1980
	13. NUMBER OF PAGES: 75
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS (of this report): UNCLASS
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

LEVEL II

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DTIC ELECTE JUL 21 1981 S D

F

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-17

23 JUN 1981

Fredric C. Lynch

FREDRIC C. LYNCH, Major, USAF
Director of Public Affairs
Air Force Institute of Technology (ATC)
Wright-Patterson AFB, OH 45433

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ATTACHED

81 7 16 008

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD A101628

DTIC FILE COPY

80-61R

AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to ascertain the value and/or contribution of research accomplished by students or faculty of the Air Force Institute of Technology (ATC). It would be greatly appreciated if you would complete the following questionnaire and return it to:

AFIT/NR
Wright-Patterson AFB OH 45433

RESEARCH TITLE: The Design and Implementation of a Translator for Arithmetic and Boolean Expressions

AUTHOR: Marin L. Bishop

RESEARCH ASSESSMENT QUESTIONS:

1. Did this research contribute to a current Air Force project?

( ) a. YES ( ) b. NO

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not?

( ) a. YES ( ) b. NO

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency achieved/received by virtue of AFIT performing the research. Can you estimate what this research would have cost if it had been accomplished under contract or if it had been done in-house in terms of manpower and/or dollars?

( ) a. MAN-YEARS ________ ( ) b. $________

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3. above), what is your estimate of its significance?

( ) a. HIGHLY SIGNIFICANT ( ) b. SIGNIFICANT ( ) c. SLIGHTLY SIGNIFICANT ( ) d. OF NO SIGNIFICANCE

5. AFIT welcomes any further comments you may have on the above questions, or any additional details concerning the current application, future potential, or other value of this research. Please use the bottom part of this questionnaire for your statement(s).

NAME GRADE POSITION

ORGANIZATION LOCATION

STATEMENT(s):

Accession For
NTIS GRA&I X
DTIC TAB
Unannounced
Justification
Distribution/
Availability Codes
Dist | Avail and/or Special
A

FOLD DOWN ON OUTSIDE - SEAL WITH TAPE

AFIT/NR
WRIGHT-PATTERSON AFB OH 45433

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE. $300

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 73236 WASHINGTON D.C.

POSTAGE WILL BE PAID BY ADDRESSEE

AFIT/ DAA
Wright-Patterson AFB OH 45433

FOLD IN

THE DESIGN AND IMPLEMENTATION OF A TRANSLATOR FOR ARITHMETIC AND BOOLEAN EXPRESSIONS

RESEARCH REPORT

Presented in Partial Fulfillment of the Requirements
For the Degree Master of Computing Science, Industrial
Engineering Department of Texas A&M University

By

Marvin L. Bishop

Approved by

____
Jack A. Barnes
Chairman

____
Sallie Sheppard

____
Winston T. Shearon

Texas A&M University
1980

ABSTRACT

This paper describes an algorithm for scanning commands of a specific query language for a data management system. The commands include relational, arithmetic assignment, and Boolean expressions. The algorithm accepts the expressions in conventional infix notation, transforms them into postfix notation, then into an efficient set of computing steps known as ordered triples. Structured programming is used in that extensive, indented comments form the structure and FORTRAN code carries out the instructions of the comments.

ACKNOWLEDGEMENTS

I would like to thank Rocky Manning for providing the specifications and requirements for this project. He was patient and willing to explain the system interface and uses. Jay Soper was helpful in developing structured methods for structuring and documenting the programming code. Thanks go to Dick Dickinson for allowing my participation in the project.

I am also grateful to Dr. Jack A. Barnes, the chairman of my committee, for accepting the topic for research, for his advice, and for his patience during the preparation of this paper. The remainder of my advisory committee, Dr. Sallie Sheppard and Dr. Winston Shearon, should also be thanked for their guidance throughout my graduate program.

TABLE OF CONTENTS

APPENDICIES

FIGURES

CHAPTER I

INTRODUCTION

Training personnel to perform their assigned duties is a never-ending responsibility of managers. Personnel and duties are both continually changing. Even if the personnel and the basic work to be accomplished could be considered to be constant, the approach to accomplish the work and the detailed tactics used will vary as individuals seek easier and better methods to make their work more pleasing. Managers and supervisors are also responsible for change as they blend their personality into the organization and search for more efficient, more productive, and less expensive means to accomplish the goal.

One significant aspect of the continual change in personnel and work is the appropriate training they need to properly perform the duty. Certainly they must be sufficiently trained to achieve a certain level of proficiency to make them productive in the job. However, over training or training in tasks which they do not perform is an unnecessary expense and thus should be avoided if at all possible. To optimize the benefit-training ratio, a manager should expend resources to train personnel only for

those tasks which they will actually perform on the job.

Optimized training appears ideal when considering one person and one job which can be specifically defined or if numerous individuals are performing exactly the same duties. This ideal situation seldom occurs in the real world. A more plausible situation within a given organization is for a number of the employees to perform identical or similar tasks for a certain portion of their work-week, but only a few employees would be doing tasks which are identical or sufficiently similar such that the same training curriculum would be suitable.

The next logical step in analyzing training requirements is an effort to identify, categorize, and group the tasks performed. As an example, suppose employee A spends 50% of his time performing task 1, 30% perfoming task 2, and 20% perfoming task 3. Employee B's time is distributed as 30% on task 1, 60% on task 3, and 10% on task 4 which employee A did not perform. For employee C, assume a distribution of 40% on task 2, 20% on task 3, and 40% on task 4. The overlap of duties is quite evident and considering economy of scale, all employees should be trained together instead of a training program being customized for each of them. On the other hand, training employee A on task 4 is a wasted effort. To obtain maximum return for training resources expended, the employees should

be grouped for the various training sessions. Employees A and B would be trained on task 1, A and C on task 2, A, B, and C on task 3, and A and C on task 4. With this grouping the employees are trained on only those tasks which they will be performing (no training is wasted) and the training classes are as large as possible (or feasible) for economic considerations.

Expanding the example to a large organization of several hundred employees performing various tasks can provide considerable savings if the job analysis is properly conducted. The same information used to conduct the job analysis may also be quite beneficial for preparing job descriptions, reassigning tasks to employees, reducing time consuming tasks, identifying problem areas, and in general improving the overall effectiveness of the organization.

This is where occupational analysis can be effectively used. Occupational analysis is one means of collecting data about the tasks performed within an organization. It includes collecting information about the job from the people, their supervisors, and others. Occupational analysis is well accepted throughout the world and is used extensively by military services, civilian governments, universities, and industry (2).

In gathering the information, respondents are asked to indicate on a relative scale how much time they spend

performing the different tasks listed on a questionnaire. Their responses are processed to provide a percentage of time devoted to the various tasks. In addition to the task related information, history and secondary data is often gathered, again through responses to written questions. History data will usually include age, sex, race, skills, experience in the position, and similar information. Secondary data is normally related to how important each task is or how much training is required for each task. The data collected is in a quantified form or can be readily converted to quantified form. It should be obtained from a large sample of respondents to minimize the effect of perturbations. It is in the processing and analysis of the responses that the computer plays a significant role.

The Air Force has been one of the pioneers in occupational analysis. In the early sixties, they began developing several computer programs to do the analysis, a system which has become known as the Comprehensive Occupational Data Analysis Program (CODAP). Since the beginning of CODAP and as more experience in occupational analysis was gained, several programs have been added to the system to increase its capability. Unfortunately, no overall system design existed and the documentation left much to be desired. As might be expected and too often experienced, this evolutionary process resulted in a system

which is difficult to modify and not totally responsive to the needs of the users. Realizing the limitations of the original system, the Occupational Research Program of Texas A&M University is under contract with the U.S. Navy to rewrite the programs. Following the initial analysis of the system and through consultation with the Navy, other military services, and other CODAP users, it was agreed that an entirely new design of portions of the system would be preferable to just rewriting existing programs. The new design should emphasize documentation, understandability, modifiability, and transportability while providing increased data manipulation capability at a decrease in cost and time involved.

The data gathering, editing, sorting, and creating of the initial data files were included in the rewrite portion of the system. The portion which is being redesigned includes a consolidation of programs which will manipulate the data in the files. The data manipulation programs will be based on an interpreter which processes statements of the newly designed CODAP language.

With this introduction to job analysis and the CODAP rewrite project, the remainder of this paper will focus on the design of a small segment of the CODAP programs. An interpreter to manipulate the CODAP data base is discussed in chapter 2. Chapter 3 delineates the overall design

objectives of achieving good, useful software and the application to the programs being developed. A detailed description of the program logic and interface is in chapter 4. Chapter 5 summarizes the paper and suggests areas which may be of interest for additional work.

CHAPTER II

THE INTERPRETER

The decision to redesign the portion of the system which manipulates the data was based in part on a desire to provide a more natural, easier to use system. The original CODAP system was quite tedious since users were required to indicate their desired data manipulation action by placing numbers in specified card columns. This procedure was slow and quite prone to inducing errors. To overcome this problem, it was decided to use free format, easily understandable English-like commands.

The Statistical Analysis System (SAS) language nearly satisfied the above requirements but was not totally satisfactory (7). Some of the actions in occupational analysis are quite unique. Consequently a new language, the CODAP language, was developed to enhance the usefulness of the system. The new CODAP language is designed to permit convenient manipulation of the job analysis data. The data, which is logically stored in table format, can be manipulated by either rows or columns with nearly equal ease.

Since the purpose of this paper is to present the design and implementation of only a portion of the CODAP interpreter,

the language is not covered in detail. Only those portions of the language applicable to this paper are explained. A full description of the CODAP language may be found in the CODAP User's Manual (5).

This paper is limited to the design and implementation of modules which will handle the "full assignment clause" and the "Boolean expression". The syntax graphs which illustrate these two commands are in appendix 1. The lines indicate the possible paths which may be followed. A divergence of lines means either path is possible. Circles and ovals denote the enclosed expression is to be included in the command string exactly as specified.

As an example, consider the full assignment clause. It may consist of a simple assignment clause or the IF-THEN-ELSE expression which may have one or more nested IF-THENs, but only one ELSE-clause. A possible full assignment clause, as expressed in the CODAP language, might be

```
IF Bill = 3 THEN Tom := 5
IF Bill = 4 THEN Tom := 6
                 ELSE Tom := 1 'comment'.
```

The full assignment clause is the major portion of the CREATE command which may be used to add new columns or rows to the data base. The "Bill = 3" portion is a relational expression which is tested for a true or false indication to determine which assignment clause is executed. Only one

assignment clause of the full assignment clause will be executed.

A typical Boolean expression for selecting a subset of the CODAP data base might be

IN G1 .AND. ((T1 <= 3) .OR. (T4 = 5)).

The "IN G1" indicates only the group of columns included in the label G1 are to be considered. "NOT IN" is an alternate indicator of which groups are to be excluded. "T1 <= 3" indicates only those columns where the T1 variable is less than or equal to three will be accepted. However, in the above example, if the T4 variable is five, the value of T1 may be greater than three and the column is still considered. The relational expressions "T1 <= 3" and "T4 = 5" are the operands for the ".OR." logical operator. The operands for the ".AND." operator are "IN G1" and the interim result of ((T1 <= 3) .OR. (T4 = 5)).

It is possible to structure the source language for direct execution. However, such a procedure does restrict the flexibility in formating the source language and reduces the efficiency of program execution. For complex source languages which have a somewhat complicated goal it is common practice to first translate the source language into an internal form which is easier to handle mechanically. In most internal forms, the operators normally appear in the order in which they are to be executed (3). Long command

strings or sentences are broken down into short phrases of a single operator and the necessary operand(s). The program which does the translation places the phrases in the proper order for execution. Thus the execution program does not need to be concerned with precedence of operators, but has the simplified task of executing in order of sequence, one at a time.

Arithmetic and Boolean expressions, as commonly written, can be quite complex for a computer to process. The normal expressions used are known as "infix notation" since the binary operators are placed between the two operands on which they are to operate. Unary operators are placed immediately in front of their respective operand. To establish a single, correct sequence of execution of the operators, the operators are generally assigned a precedence--those of a higher precedence being executed before those of a lower precedence. The precedence execution order can be modified by the use of parentheses executing the expression enclosed by parentheses before the operatoions outside the parentheses.

Human beings find the infix notation quite understandable since it is the most commonly used system and they have generally been exposed to it since their earliest arithmetic classes. The ability to scan and comprehend more than one symbol at a time coupled with the free use of parenthesis, sometimes added merely to improve clarity, aids in the

comprehension of this notation. However, a mechanical device, or electronic in the case of a computer, does not possess the same capability as humans and thus does not respond as well to infix notation. A computer is essentially restricted to considering a single symbol at a time and comparing that symbol with another. Further, parentheses which humans add for clarity are an unnecessary added symbol to the computer, requiring additional processing time. Consequently, to aid the computer, infix expressions are often translated into another form such as suffix or postfix notation.

Postfix notation will be used in the CODAP interpreter. Parentheses are not required in postfix notation and operators are placed in exactly the order in which they are to be executed. This eliminates the possible confusion of operator precedence and reduces the number of symbols which the computer must process. As examples, A + B would be written as AB+ in postfix notation; and A + B * C as ABC*+. It should also be noted that the varibles and constants appear in exactly the same order in both infix and postfix notation, and in postfix the operands appear immediately to the left of the operators.

Once an expression has been converted to postfix notation, a second conversion is easily accomplished to achieve a convenient form for a single binary operator--a triple.

The triple may be expressed as

(<Operator>, <Operand 1>, <Operand 2>)

where <Operand 1> and <Operand 2> specify the arguments for the operator. As an example, A + B might be represented by

+, A, B

and A * B + C * D could be represented by the sequence

1. *, A, B
2. *, C, D
3. +, (1), (2).

The numbers in parentheses indicate that operand is the interim result obtained from the triple row illustrated (see reference 3). Interim results are often pushed onto a stack, then popped from the stack whenever required in a succeeding triple. For unary operators, one of the operand positions is left blank. The significance of ordered triples is that the triples appear in the sequence in which they are to be executed. Once an expression is in ordered triple form, it can be efficiently executed numerous times by a computer.

The objective of the module designs discussed in this paper is to accept the numerical tokens of normal infix notation which are the English-like commands as input. These commands are converted to postfix notation where necessary for easier processing. The tokens are then placed in an ordered triple array which is the output from the modules. Chapter 3 discusses the considerations of

good design which will be applied in the design of these modules.

CHAPTER III

DESIGN CONSIDERATIONS

Several factors should be given careful consideration when beginning the design of computer software. The software should be understandable, modifiable, reliable, useful transportable, and efficient. Understandable code can be produced by good documentation techniques. The documentation should be adequate to meet the needs of the user and those responsible for maintaining the software. It should be standardized and uniform. External documentation should provide an overall design of the program modules and the relationship with calling and called modules. In line comments should be sufficient to allow reasonably knowledgeable programmers to easily follow the logic and understand the code. The comments in the programs produced for this report set the structure of the main program logic and the code carries out the logic of the comments.

Software which is understandable has a head start on being modifiable. If it can be understood, it can usually be modified. Additionally, tricky code should be avoided. It should be modularized, each module performing a single function. Thus any necessary changes will affect the

fewest number of lines of code possible. Subroutines should be completely contained on one page to allow an easy overall view. Subroutines developed for this project have been limited to less than 100 lines of code which should be comprehendable to any programmer familiar with the programming language.

To be reliable, the code should respond appropriately with any and all of the possible range of input data which it might encounter. The command string which is to be provided to the modules under consideration will have been previously checked for syntax errors. Consequently few routines have been included for handling erroneous input. This also conforms with the specifications provided. Disallowing syntax errors, reliability can be checked by testing the range of possibilites of acceptable input. Although not all possible combinations can reasonably be tested, sufficient variations of input should be encountered to cause each part of the code to be exercised. Such a procedure should provide a high degree of reliability.

To be efficient, the code should execute in minimal computer time. Programming shortcuts and machine dependent techniques are methods used to improve efficiency. Both are contrary to the goals of understandable, modifiable, and transportable. Consequently some loss in efficiency will be accepted to enhance other goals.

Transportability is of major concern for the CODAP programs. They will be used by various agencies on numerous makes of computers and should perform well on all occassions. To enhance transportability standard ANSI FORTRAN has been selected as the language for all modules. It is common enough that any facility of resonable size would likely already have, or can reasonably acquire, the necessary FORTRAN compiler.

The last and probably the most important goal discussed is usefulness. To be useful, the code must perform the desired process for which it was produced. This is verified by a rigorous test effort, inputing test data and carefully checking the output for the intended results. The system will be useful to more facilities by using a common programming language, FORTRAN, as discussed with transportability.

Structured programming has been used extensively throughout. A top-down approach was taken to break the problem in to manageable portions and to enhance the goals of understandable, reliable, and modifiable code. A hierarchy chart of the system designed can be found in Figure 1. The program structure could have been improved using a language with structured constructs, such as PL/I or ALGOL. However, FORTRAN was the specified language. Therefore, to provide as much structure as possible, comments are plentiful and structured in nature. The "if-then-else" construct is used

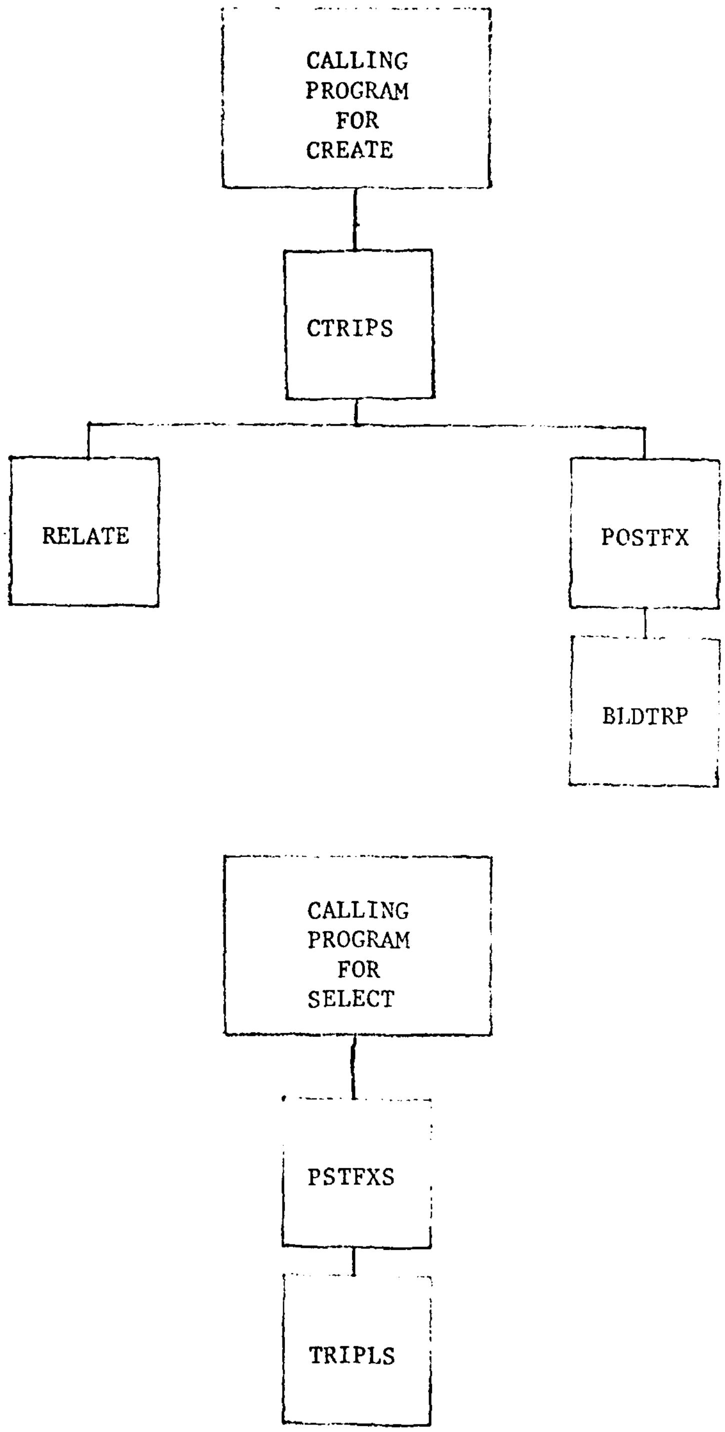


Figure 1. Hierarchy Chart

frequently to begin the comments associated with a condi-
tional statement. Indentation is employed to provide a visual indication of block structure and the range of the if-then-else construct. The comment "end of if" signifies the end of an if-then-else block of code. Although such an approach requires an abundant use of GO TOs, they are the only means of transferring control for a conditional construct in the FORTRAN language. Usually the GO TO construct should be avoided as much as possible to make code easy to follow. However the author believes the structure of the comments and indentation along with the controlled use of GO TOs has resulted in a well structured and quite understandable program considering the limitations of the FORTRAN language.

Based on the overview of the design philosophy, chapter 4 will describe in detail the algorithms used. It will descibe logic used to transform command strings into ordered triples.

CHAPTER IV

DESCRIPTION OF ALGORITHMS

The purpose of this project was to design and implement modules to perform two separate functions. Both the full assignment clause and Boolean expressions needed to be transformed into the internal form of ordered triples for efficient execution. Although the two outputs were to be of the same format, separate processes were desired since the inputs are not sufficiently similar. This is also in agreement with the good software engineering techniques of one function per module which enhances program understandability. The programs to process the full assignment clause were developed first. These were used as a starting point for developing the programs which process the Boolean expressions.

Full Assignment Clause

The full assignment clause, as discussed in chapter 2, consists of an IF-THEN-ELSE clause. The IF portion is optional and if present is composed of a simple relational expression. The objects of THEN and ELSE will be an arithmetic expression whose value is computed and assigned to a variable. The syntax graph appears in appendix 1.

The full assignment clause example presented in chapter 2 is repeated here for clarity.

IF Bill = 3 THEN Tom := 5

IF Bill = 4 THEN Tom := 6

ELSE Tom := 1 'comment'.

When transformed to ordered triples this expression becomes

Row	Operator	Operand 1	Operand 2
1.	SUB	Bill	3
2.	BNZ	POP	(5)
3.	:=	Tom	5
4.	B		(10)
5.	SUB	Bill	4
6.	BNZ	POP	(9)
7.	:=	Tom	6
8.	B		(10)
9.	:=	Tom	1

To form the above triples, all relational expressions are subtracted. The execution phase will push the interim result onto a stack which may be subsequently retrieved with the POP command. Immediately following the relational triple is a conditional branch to the next assignment clause to be considered should the relational expression be false. After each assignment clause is an unconditional branch to the end of the full assignment clause, since only one of the assignments is to be executed.

When a full assignment clause is to be processed, the appropriate tokens will be passed by an array parameter to subroutine CTRIPS, the control module for creating triples. The flow chart for CTRIPS appears in Figure 2. CTRIPS checks

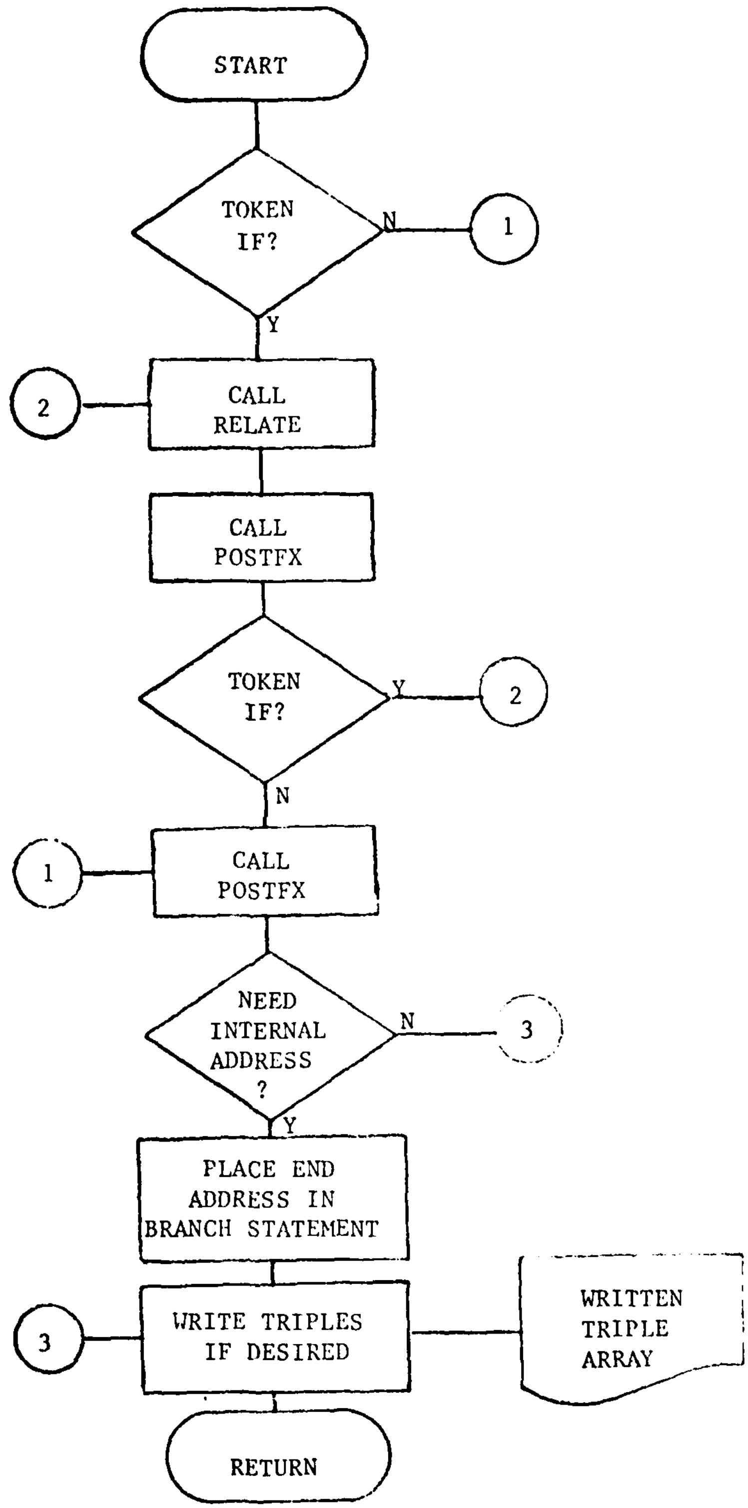


Figure 2. Flow Chart For CTRIPS

for an IF-token and if found calls subroutines RELATE and POSTFX. On return from POSTFX, another check is made for an IF-token which exists for nested IF-THENs. If found, the program loops back until the ELSE-token is encountered which will generate a call of POSTFX to process the ELSE assignment clause. Upon the final return from POSTFX a check is made to verify the requirement for internal addresses within the triples. This requirement exists whenever the full assignment clause contains the IF-THEN-ELSE tokens, that is anytime it consists of more than a single, simple assignment clause. The needed address is the address of the end of the triples and will become the operand for the unconditional branch at the end of each set of triples representing a simple assignment clause. The triples are then written out if desired for maintenance or debugging purposes and the subroutine returns to the calling module.

Subroutine RELATE processes the relational expression following the IF-token and places it in the ordered triples. The flow chart is illustrated in Figure 3. Relational expressions are limited to the following components:

1. Optional string of unary pluses and/or minuses;
2. Constant or variable identifier;
3. Relational operater;
4. Optional string of unary pluses and/or minuses;
5. Constant or variable identifier.

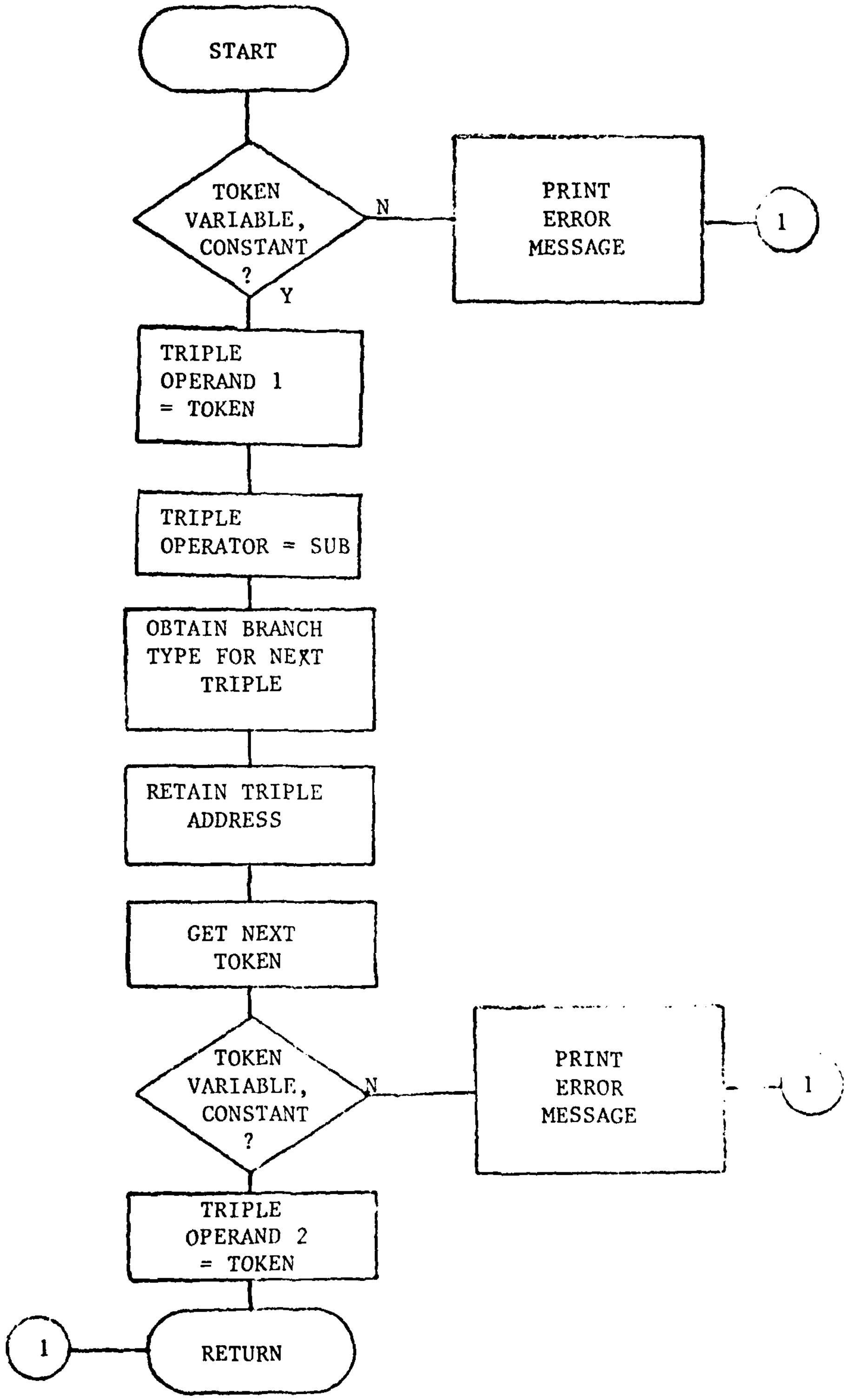


Figure 3. Flow Chart For RELATE

Unary pluses are dissregarded since they have no effect. Unary minuses will negate the constant or variable token on which they operate. (The processing of unary pluses and minuses is a minor detail which does not appear in any of the flow charts for sake of simplicity.) The operands of the relational operator (variables and/or constants) are placed in the second and third columns of the triple array. An internal code for subtract is placed in the first column of the triples as the operator.

A branch condition based on the specific relational operator is placed in the next triple. The address of this triple is saved for inserting the object of the branch at a later time when it becomes known. This occurs in subroutine BLDTRP. The purpose here is to generate a branch to the end of the THEN assignment clause should the relational expression be false. The address of the end of the THEN-clause is not known until BLDTRP completes building the triples for the THEN assignment clause.

Subroutine POSTFX receives the string of tokens representing a simple assignment clause such as

A := B * (C + D ** E) - Sqrt (F).

With this input, POSTFX transforms the token string into postfix notation which would be

A, B, C, D, E, **, +, *, F, Sqrt, -.

BLDTRP is then called to build the ordered triples from the

simple assignment clause. The flow chart in Figure 4 illustrates the basic algorithm used.

Input tokens are parsed one at a time and, depending on what they represent, either moved directly to the output stream or pushed onto a last-in-first-out (LIFO) stack for an interim period. When the "end" token is encountered, any tokens remaining on the stack are moved to the output stream. Since the order of variables and constants as read from left to right is the same for both infix and postfix notation, they are always moved directly to the output stream. The order of operators is changed as necessary to obtain the proper sequence of execution. The standard precedence of operators from highest to lowest is:

Functions

Unary plus or minus (+, -)

Exponentiation (**)

Multiplication, division (*,/)

Addition or subtraction (+, -)

Assignment (:=)

Right parenthesis

Left parenthesis

A series of relative comparisons result in the proper sequence of operators. A left parenthesis is always pushed onto the stack. When the stack is empty the operator is pushed onto the stack. Plus and minus signs must be checked

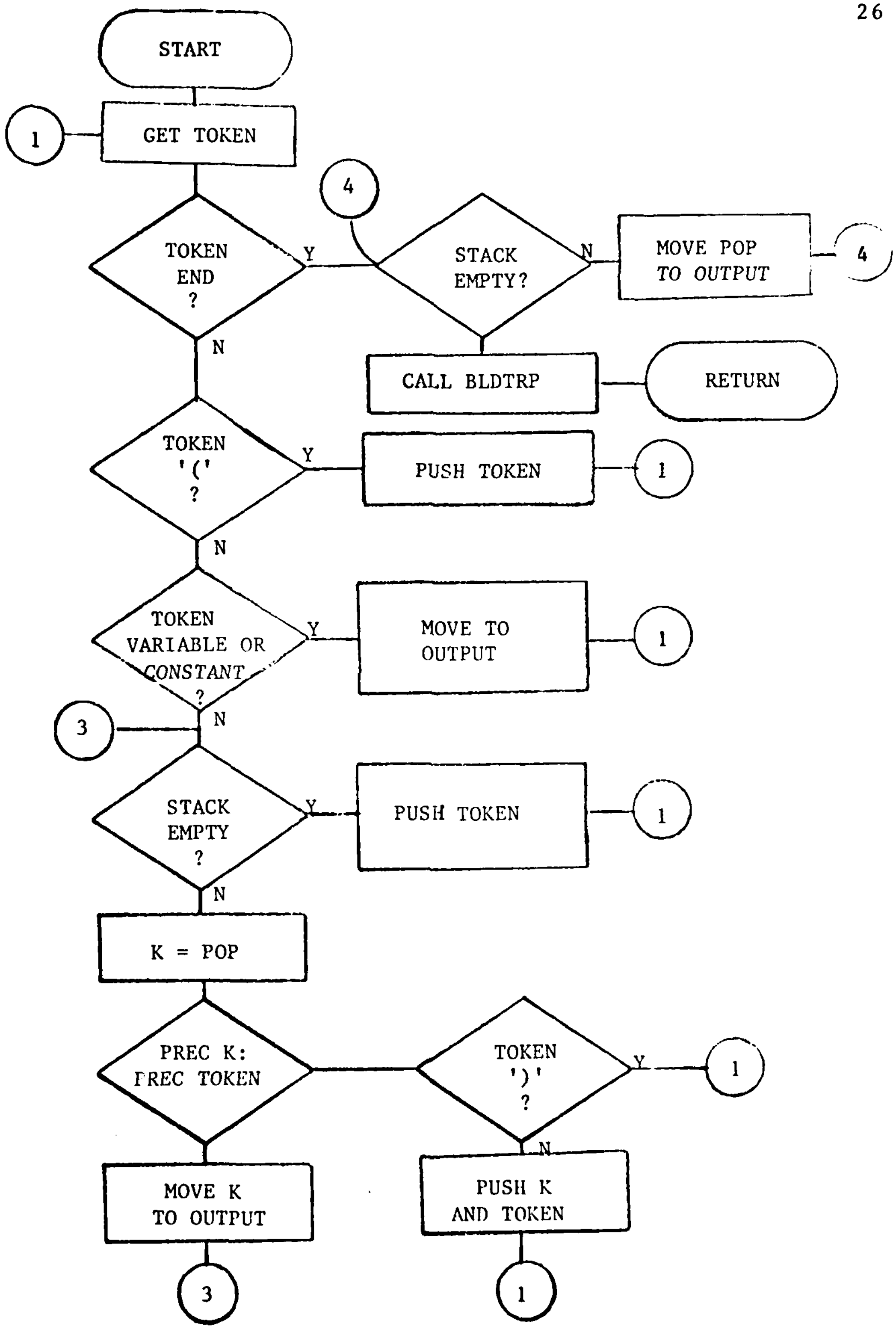


Figure 4. Flow Chart For POSTFX

to determine if they are unary or binary operators. Unary pluses are disregarded while each unary minus negates its operand token. Remaining operator tokens are compared with the token at the top of the stack. If the stack token is of equal or higher precedence, it is output and another comparison is made with the new top of the stack token. When the input token is of higher precedence and a right parenthesis, then the stack token must be a left parenthesis, so both are discarded. In other cases when the input token is of higher precedence it is pushed onto the stack and the next token is fetched.

The simple assignment clause has four possible delimiters to mark its end. A second IF-token indicates a nested IF-THEN situation and a relational expression will follow. An ELSE-token marks the end of the THEN assignment clause which will be followed by an ELSE assignment clause. The tokens NOSAVE and COMMENT are special tokens to denote the end of the full assignment clause. When any of these delimiters are encountered, the stack is moved to output and an internal end delimiter is placed in the output stream. POSTFX then calls BLDTRP to convert the postfix assignment clause into ordered triples.

Subroutine BLDTRP builds triples from the postfix expression. Figure 5 is the flow chart for BLDTRP. Using the while-do construct, the underlying logic is "while the token

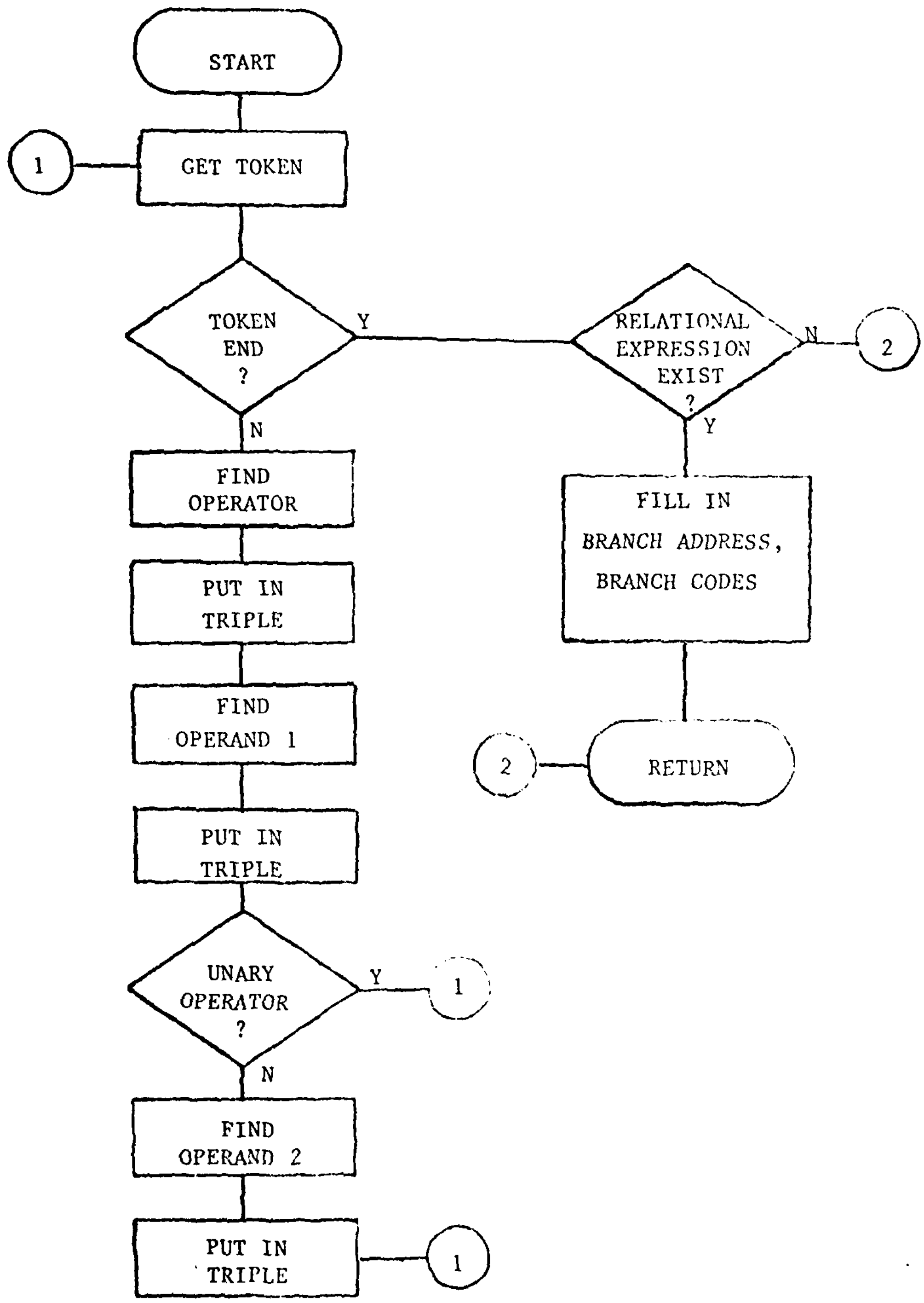


Figure 5. Flow Chart For BLDTRP

is not the internal end delimiter, to place the operators and operands into the proper position in the array of ordered triples".

The postfix token string is parsed until an operator is found. That operator and the preceding two operands (one operand for function operators which are unary operators) are placed into the triple array. After being inserted in the triple, a zero replaces operator tokens in the postfix string. This step will prevent any attempt to use the same operator twice. It should also be noted that the interim result of a triple (an operator and its respective operands) may be the operand for a subsequent triple. Thus the right operand in the postfix string is replaced with a POP command to denote the interim result of a preceding triple is to be popped from a stack. (During execution, interim triple results will be automatically pushed onto a stack for later use.) After the second operand is placed in the triple a zero is placed in its position in the postfix string to preclude that operand from being used a second time.

The subroutine then finalizes some addresses within the ordered triples. The conditional branch for a false relational expression (false IF condition) is given the address of the present triple plus two (the beginning of the ELSE-clause). The next triple is given an unconditional branch to the end of the full assignment clause. As only one assign-

ment clause is to be executed, each clause is followed with a branch to the end of the last assignment clause. Because that address is not known yet, the address of the end of each simple assignment clause is retained and the final "end" address is inserted in each in a wrap-up procedure in CTRIPS.

Boolean Expression

The Boolean expression, as discussed in chapter 2, consits of a series of relational expressions which are the operands of logical operators. They have the same possible syntax as the full assignment clause relational expressions presented earlier. The tokens IN and NOT IN and their group identifier are also possible operands, indicating data is to be either selected from the specified group of columns of the data base or selected from columns not within the specified group. Parentheses may also be used to modify the precedence of operators or to improve understandability of the expression. An example of a proper Boolean expression might be

IN G1 .AND. T1 = 3 .AND. (T2 <= 2 .OR. T2 > 5).

After transforming this expression into postfix notation it would appear as

IN G1, T1 = 3, .AND., T2 <= 2, T2 > 5, .OR., .AND..

The string of tokens in postfix order must now be converted into ordered triples for efficient execution. The desired

ordered triples for the preceding expression are as follow:

Row	Operator	Operand 1	Operand 2
1	IN		G1
2	SUB	T1	3
3	BNZ	POP	(6)
4	ADD	0	1
5	B		(7)
6	ADD	0	0
7	AND		
8	SUB	T2	2
9	BP	POP	(12)
10	ADD	0	1
11	B		(13)
12	ADD	0	0
13	SUB	T2	5
14	BMZ	POP	(17)
15	ADD	0	1
16	B		(18)
17	ADD	0	0
18	OR		
19	AND		
20	SETMSK	POP	SELECT

During execution of the above triples the relational evaluations and the conditional and unconditional branches function identical to those explained previously with the full assignment clause. The IN group operand will cause a one to be pushed onto a stack if the group exists, otherwise a zero will be pushed. The "ADD 0 1" triple is executed if the relational expression is true and will cause a one to be pushed onto the stack. For a false relational expression, the "ADD 0 0" triple is executed, causing a zero to be pushed onto the stack. The AND triple will pop the stack twice and if there are two ones, a one is pushed, otherwise a zero is pushed. Similarly, OR pops the stack twice and pushes a one if at least one of the pops is a one. Row 20

sets a mask or flag to one if the Boolean expression is true, otherwise a zero is set.

Obviously there are many similarities between building ordered triples for Boolean and arithmetic expressions. However sufficient differences exist to warrant separate routines. To preclude excessive repetition, the description of the full assignment clause modules will be used as a base line and only the significant differences for Boolean expressions will be explained in this section.

When a Boolean expression is to be translated, the main program will call subroutine PSTFXS, a six letter name for "postfix select". The flow chart for this subroutine is the same as that of POSTFX (Figure 4) with minor exceptions of delimiters, operators, and operands. The tokens NOSAVE and REMARK are the only delimiters for the Boolean expression. The precedence of possible operators from highest to lowest is:

.AND.

.OR.

Right parenthesis

Left parenthesis.

The operands for the Boolean expression are more than one token in length. Consequently the routine recognizes each portion of an operand (unary plus or minus, constant, variable, relational operator, IN, NOT, and group) and moves them directly to the output string. Once the expression is

converted to postfix notation, a recognizable end delimiter is placed in the string and subroutine TRIPLS is called.

Subroutine TRIPLS (Figure 6) accepts the Boolean expression in postfix notation and arranges the tokens into ordered triples. Again there are similarities, yet differences, when comparing subroutines TRIPLS and BLDTRP.

The postfix string is parsed and the tokens identified. Logical operators (.AND., .OR.) are moved directly to the triple and the next token is fetched. The operands IN and NOT IN along with the group identifier are placed in the triples. No branch conditions are required since the execution phase will determine whether these operands are true or false, pushing a one or zero as appropriate onto the stack. The only other token type is a logical operand of three tokens which form a relational expression. The subtract code will be placed in the triple followed by the two relational operands. The next triple will get a conditional branch based on a false relational expression. A one or zero, depending on a true or false relational expression, is pushed onto the stack. Finally the triples must provide for evaluating the entire Boolean expression is evaluated. To do this the stack is popped. A one indicates a true, a zero a false expression. A flag (SETMSK) is set to reflect this condition. Now that the triples are completed, TRIPLS returns to PSTFXS which returns to its calling module.

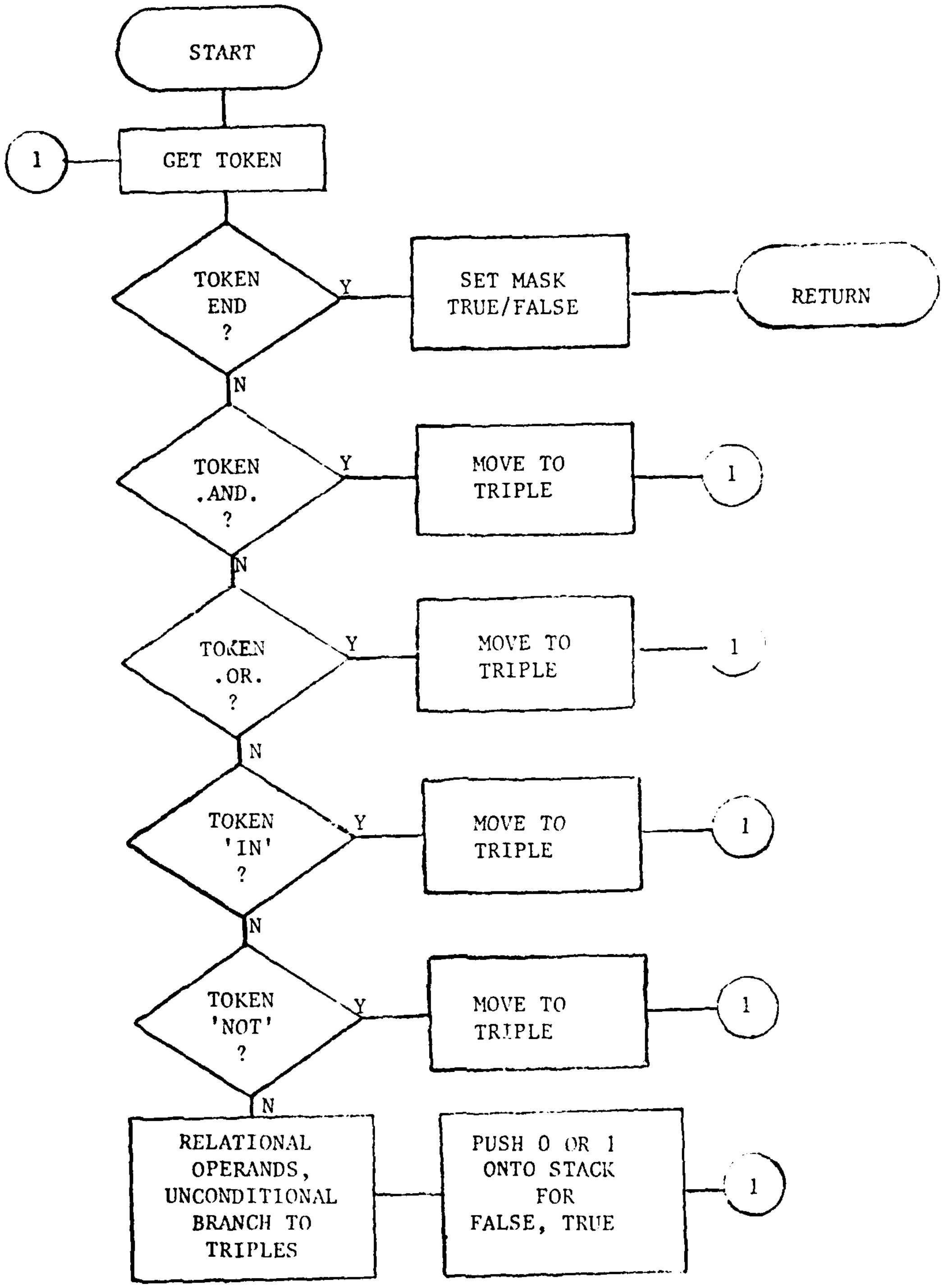


Figure 6. Flow Chart For TRIPLS

At this point, the routines to transform the full assignment clause and Boolean expressions into ordered triples have been fully discussed. The next chapter, chapter 5, will conclude this paper.

CHAPTER V

CONCLUSION

This project has been successful in developing the desired programs. Several varying sets of data have been processed and the desired results have been obtained. It should be emphasized, however, that the programs are quite sensitive to receiving syntactically correct input. It was assumed in the specifications that the tokens would be edited and checked for correct syntactic order before being processed into ordered triples. Consequently, these programs have a very low tolerance to erroneous input.

FORTRAN was specified as the programming language in order to enhance transportability. ANSI FORTRAN is generally considered to be an unstructured language since its only means of changing the order of execution of statements from sequential is with GO TOs and the DO-loop. However, it was possible to provide a perception of structure to the programs. This was accomplished by a carefully structured use of comments and precise indentation of comments and executable statements. The resulting code is more understandable than most FORTRAN programs.

The most difficult aspect of the project was defining

and understanding the specifications and requirements of the project. Nearly all of the communication was oral which may be subject to different interpretation and may often be forgotten or take on different meanings after a period of time. Further, the author was not involved in the overall CODAP project, thus initially did not have the broad perspective of the CODAP system. With attention focused on only the poblem at hand, it was often more difficult to understand the need and reason for certain specifications. Finally, the specifications were not precisely available at the start of the project. Specifications are normally developed or modified as the project progresses, as was true in this situation. As experienced in probably all software development projects, the specifications evolve and change as time passes, the users think of other requirements and peculiarities, and the designers perceive new and expanding capabilites. Real world experiences encountered in this project will certainly be of significant value to the author.

Future Efforts

Although the subroutines developed function according to the specifications, additional improvements could still be added. Separate subroutines were developed for transforming the input tokens into postfix notation, then

into ordered triples. The separate subroutines were chosen to break the overall problem down into smaller, more manageable problems and to make them small enough to be easily understood. This does, however, increase the computer overhead devoted to linking the various subroutines together. Algorithms exist (1,6) to convert an infix token string directly into ordered triples. A comparison between the length, complexity, and execution efficiency of the two methods may be enlightening.

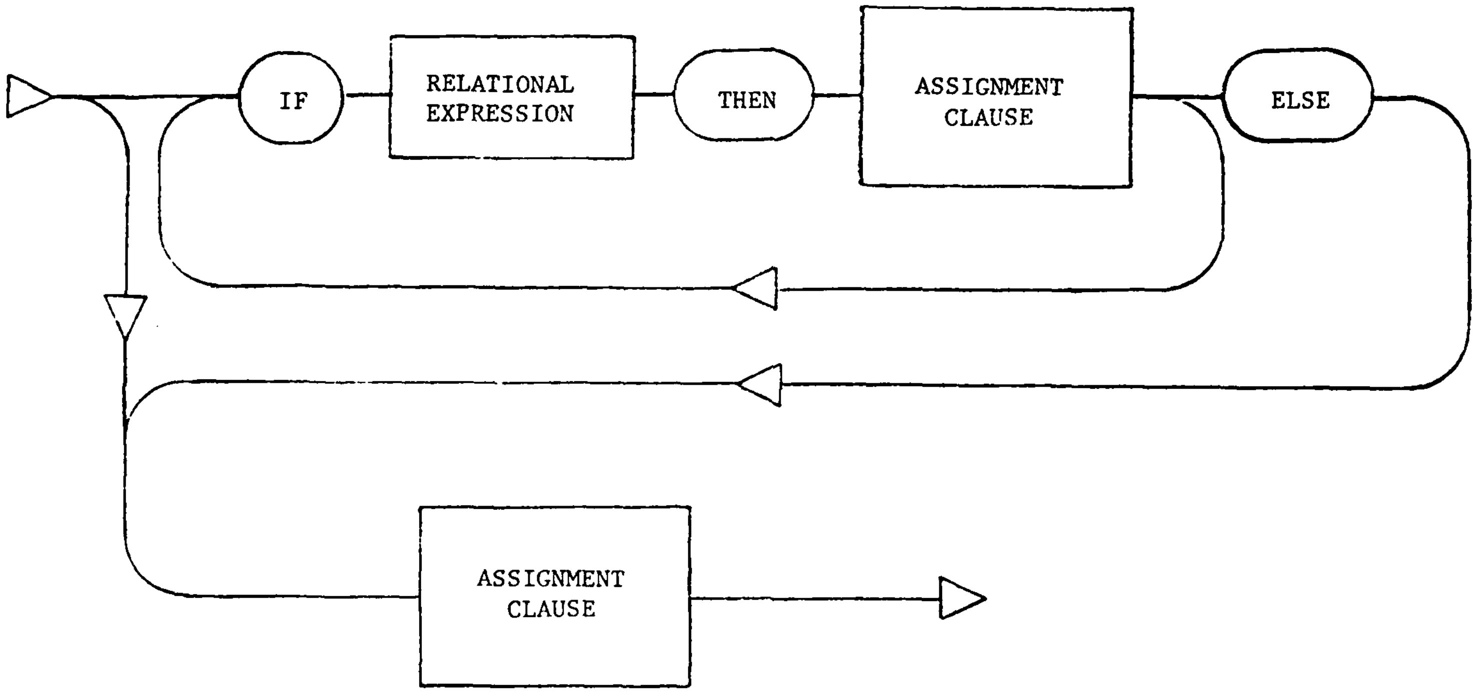
A second area for future study concerns the ordered triples constructed from the Boolean expression. The Boolean expression is composed of a series of logical operators (.AND., .OR.) and the associated operands. As developed, the entire set of triples must be executed to determine the result of the expression. However, for certain sequences of operators, it can be determined that the expression is false before the entire expression is evaluated. This would be desirable since there is no need to evaluate the remainder of the expression once the final results have already been determined. Being able to stop the expression evaluation once its results have been determined would save execution time. But developing the algorithm to insert the proper branches into the triples is not an easy problem, considering the various possible sequences of operators and how parentheses are used to

change the the normal precedence of execution. Such an optimizing step would likely require the tokens to be scanned several times while developing the possible paths through the Boolean expression. Due to the complexity, such an optimizing effort could likely result in errors as are sometimes encoutered with commercial optimizing compilers.

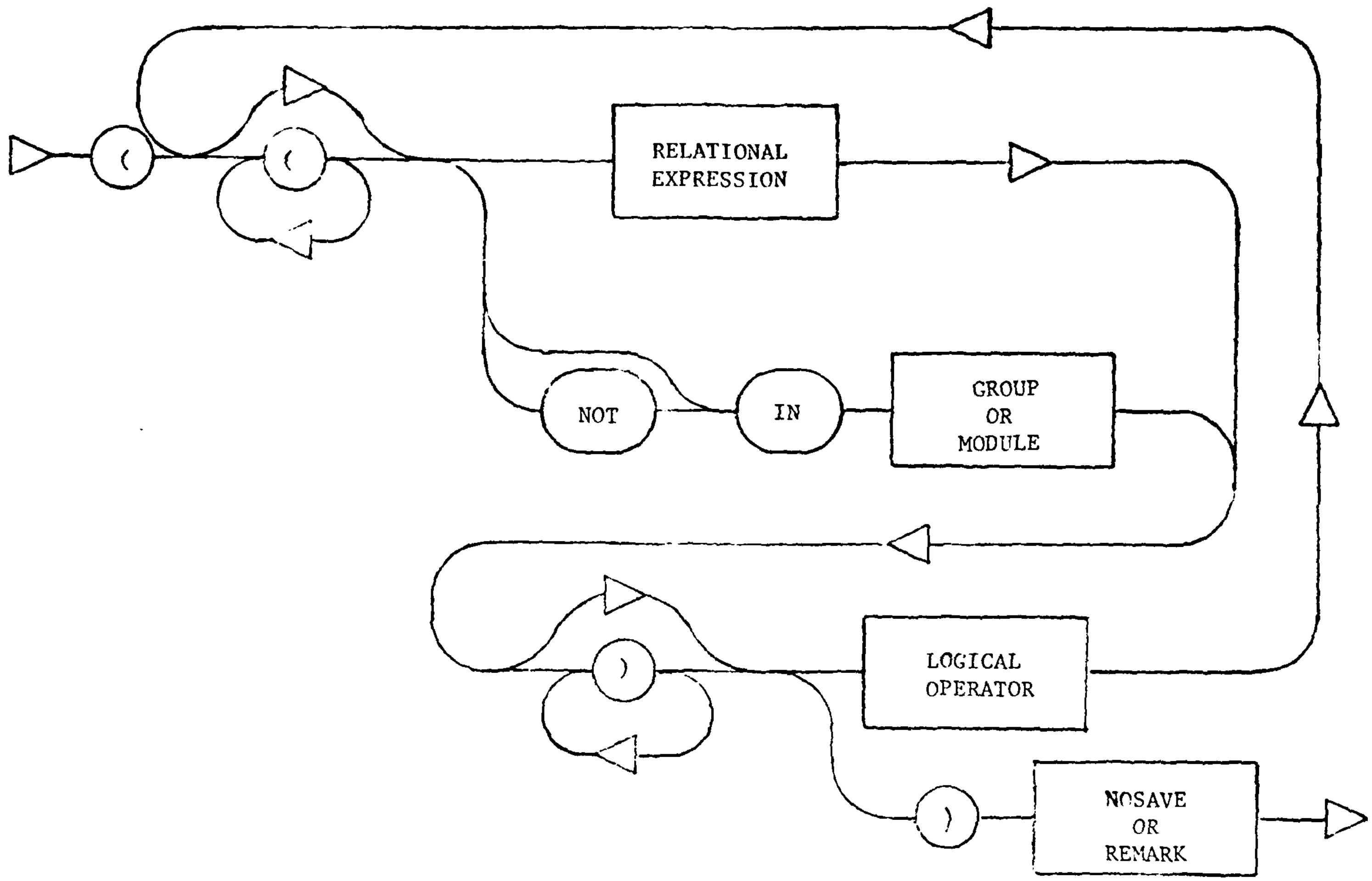
APPENDICIES

APPENDIX A

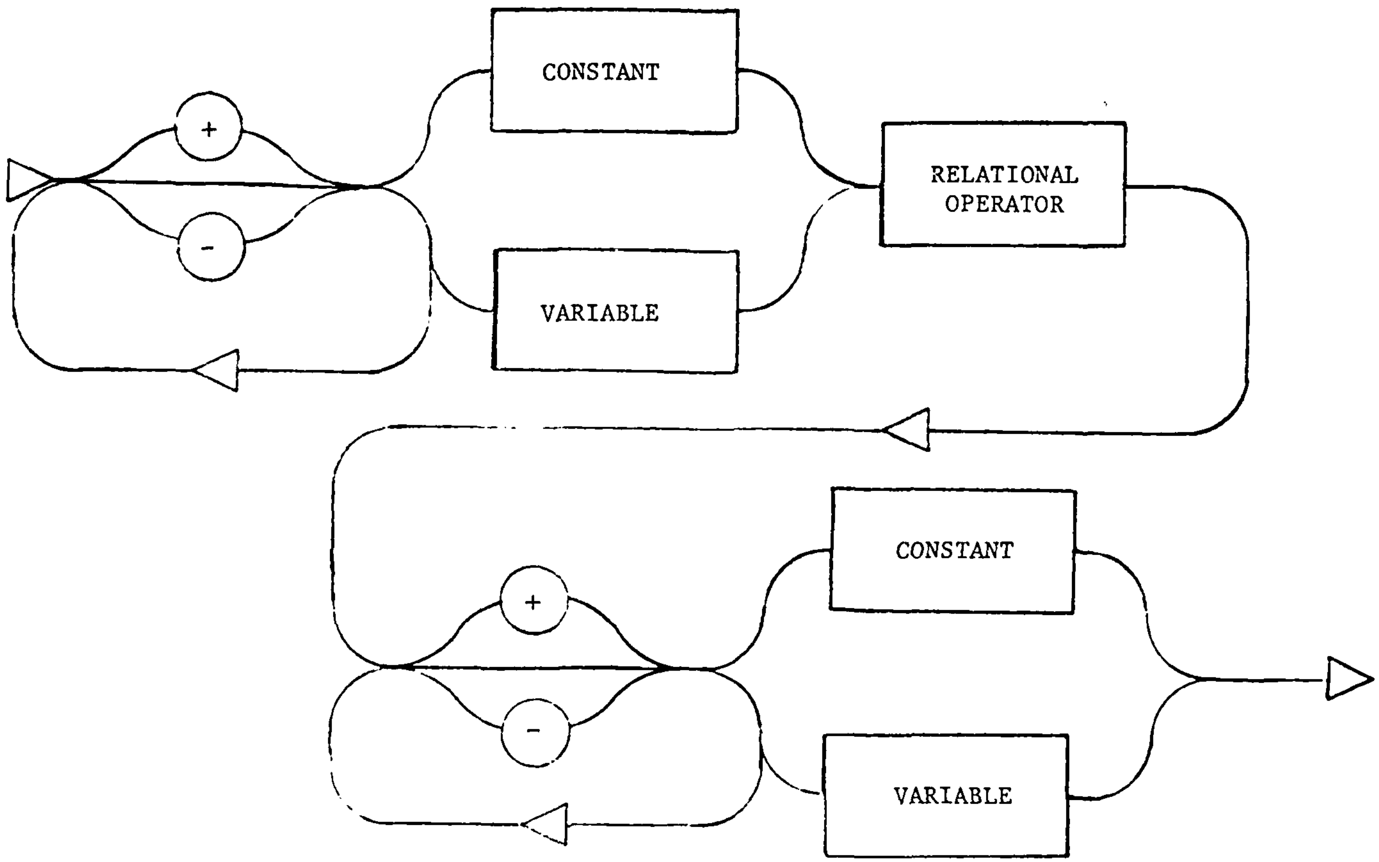
SYNTAX GRAPHS



Full Assignment Clause Syntax Graph



Boolean Expression Syntax Graph



Relational Expression Syntax Graph

APPENDIX B

USER'S GUIDE

USER'S GUIDE

The modules are designed to accept an input array of 100 tokens. If it is determined that longer commands will be used, the arrays INPUT and OUTPUT will need to be dimensioned to a larger size in all subroutines. Additionally, the matrix which returns the ordered triples, TRIPLE, may need to be enlarged. Its present size is 80 by 3.

A stack is used in the subroutines POSTFX and PSTFXS to temporarily hold operators while they are being reordered from infix to postfix notation. The stack size is 30. It is conceivable, although unlikely, for very long strings of input tokens and with certain arrangements of operators, operands, and parentheses, for the stack to overflow. If this should occur, the stack size should be increased.

PRTLVL is an integer parameter which permits printing out interim data for maintenance or debugging purposes. For a value of zero, the postfix string of tokens and the completed ordered triples are printed.

The tokens must be in proper syntactic order when passed to these subroutines. The specifications were for other modules to do the editing and syntax checking. The designed subroutines have little fault tolerance for improper tokens or incorrect token order.

Each token string must have an acceptable delimiter to denote the end of the string. Anticipated delimiters are NOSAVE or REMARK.

The tokens applicable to the programs designed are:

10000-19999	comment
20000-29999	constants

Relational Operators

30001	.EQ.
30002	.NE.
30003	.GT.
30004	.LT.
30005	.GE.
30006	.LE.

Logical Operators

40001	.AND.
40002	.OR.

Mathmetical Operators

50003	left parentheses '('
50004	right parentheses ')'
50005	plus '+'
50006	minus '-'
50007	divide '/'
50008	multiply '*'
50009	exponentiation '**'
50010	assign ':='

Functions

60002	logarithm
60009	square root

Variables

70000-109999 and 150000 or larger

Specific Identifiers

140805	IF
140806	IN
141607	NOT
142408	THEN
142409	ELSE
144002	NOSAVE
144008	REMARK

Generated Internal Code

50011	BNZ	branch on not zero
50012	BZ	branch on zero
50013	BMZ	branch on minus or zero
50014	BPZ	branch on plus or zero
50015	BM	branch on minus
50016	BP	branch on plus
50017	B	unconditional branch
50018	ADD	push onto stack
50019	POP	pop from stack
50020	SETMSK	set the mask
50021	.AND.	logical and
50022	.OR.	logical or
50023	IN	in group or module
50024	NOT IN	not in group or module
50025	CREATE	create new data
50026	SELECT	select from data base

APPENDIX C

PROGRAM LISTINGS

```
       SUBROUTINE CTRIPS (INPUT, PRTLVL, TRIPLE)
C
C  XXXXX XXXXX XXXXX XXX XXXXX XXXXX
C  X       X   X   X  X  X   X X
C  X       X   XXXXX  X  XXXXX XXXXX
C  X       X   X  X   X  X         X
C  XXXXX   X   X   X XXX X     XXXXX
C
C * * * * * * * * FUNCTION OF MODULE * * * * * * * *
C
C     CTRIPS IS THE CONTROL MODULE WHICH ACCEPTS A STRING OF TOKENS
C     WHICH FORM THE FULL ASSIGNMENT CLAUSE AND CALLS THE MODULES
C     WHICH CONVERT THE STRING INTO ORDERED TRIPLES FOR EXECUTION.
C
C * * * * * * * * PROCEDURE FOLLOWED * * * * * * * *
C
C     THE FIRST TOKEN IS CHECKED TO DETERMINE WHAT IT IS.  FOR AN 'IF'
C     TOKEN, THE RELATE SUBROUTINE IS CALLED TO PLACE THE TOKENS OF THE
C     RELATIONAL EXPRESSION INTO THE ORDERED TRIPLE ARRAY.  FOLLOWING
C     THE RETURN FROM RELATE (OR IMMEDIATELY IF THERE IS NO RELATIONAL
C     EXPRESSION) POSTFX SUBROUTINE IS CALLED TO REORDER THE INFIX
C     ASSIGNMENT CLAUSE INTO A POSTFIX ASSIGNMENT CLAUSE.
C     POSTFX CALLS BLDTRP WHICH PLACES THE POSTFIX ASSIGNMENT CLAUSE
C     INTO THE ORDERED TRIPLE ARRAY BEFORE RETURNING TO THIS MODULE.
C     REPEATED CALLS OF THE RELATE AND POSTFX SUBROUTINES MAY BE MADE
C     TO HANDLE NUMEROUS RELATIONAL AND ASSIGNMENT CLAUSES.
C
C * * * * * * * * SUBROUTINES CALLED * * * * * * * *
C
C     RELATE-MOVES TOKENS OF RELATIONAL EXPRESSIONS TO THE TRIPLE ARRAY
C     POSTFX-CHANGES TOKENS OF ASSIGNMENT CLAUSES INTO POSTFIX
C            ORDER; THEN CALLS BLDTRP WHICH PLACES THOSE TOKENS INTO
C            THE TRIPLE ARRAY
C
C * * * * * * * * VARIABLE DECLARATIONS * * * * * * * *
C
C PARAMETERS
C
C     INPUT -INTEGER ARRAY, LENGTH 100, FOR PASSING TOKENS
C     PRTLVL-INTEGER, VARIALBE TO ALLOW PRINTING OF EXTRA INFORMATION
C            WHICH SHOULD BE HELPFUL IN MODIFYING OR DEBUGGING THE
C            SYSTEM
C     TRIPLE-INTEGER ARRAY, SIZE 80 BY 3, FOR RETURNING ORDERED TRIPLES
C
      INTEGER INPUT(100), PRTLVL, TRIPLE(80,3)
C
```

```
C LOCAL VARIABLES
C
C     BRADDR-INTEGER ARRAY, LENGTH 20, HOLDS INTERNAL ADDRESS OF TRIPLE
C            ROWS WHICH WILL GET UNCONDITIONAL BRANCH TO END OF TRIPLES
C     INPNT -INTEGER, POINTS TO TOKENS IN THE INPUT VECTOR
C     NUMBX -INTEGER, COUNTS THE NUMBER OF PLACES FOR UNCONDITIONAL
C            BRANCH TO END OF TRIPLES, INCREMENTS THE BRADDR ARRAY
C     OUTPNT-INTEGER, POINTS TO LAST TOKEN IN OUTPUT VECTOR
C     OUTPUT-INTEGER ARRAY, LENGTH 100, FOR PASSING POSTFIX
C            ASSIGNMENT CLAUSE
C     REMBER-INTEGER, SAVES INTERNAL ADDRESS OF TRIPLE ARRAY TO INSERT
C            ADDRESS FROM BLDTRP SUBROUTINE
C     TRPROW-INTEGER, POINTER TO ROWS OF THE ARRAY OF ORDERED TRIPLES
C
      INTEGER BRADDR(20), INPNT, NUMBX, OUTPNT, OUTPUT(100), REMBER,
     &        TRPROW
C
C * * * * * * * * EXECUTABLE CODE * * * * * * * *
C
       INPNT = 1
       NUMBX = 0
       REMBER = 0
       TRPROW = 0
C   IF THE FIRST TOKEN IS 'IF' THEN CALL SUBROUTINE RELATE
       IF (INPUT(INPNT).NE.140805) GO TO 80
   70     INPNT = INPNT + 1
          CALL RELATE (INPNT, INPUT, REMBER, TRIPLE, TRPROW)
C   END OF IF
C
       CALL POSTFX (BRADDR, NUMBX, INPNT, INPUT, OUTPUT, PRTLVL,
     &       REMBER, TRIPLE, TRPROW)
C
C   IF THE NEXT TOKEN IS 'IF' (NESTED IF-THEN CLAUSE)
C      THEN CALL SUBROUTINE RELATE
       IF (INPUT(INPNT).EQ.140805) GO TO 70
C   END OF IF
   80  CALL POSTFX (BRADDR, NUMBX, INPNT, INPUT, OUTPUT, PRTLVL,
     &       REMBER, TRIPLE, TRPROW)
C   IF INTERNAL TRIPLE ADDRESSES ARE INCOMPLETE
       IF (NUMBX.EQ.0) GO TO 100
C      REPEAT
C      PLACE THE SAVED TRIPLE ROW ADDRESS IN THE PROPER PLACES AS THE
C         OBJECTS OF THE UNCONDITIONAL BRANCHES.
          DO 90 K = 1, NUMBX
   90        TRIPLE(BRADDR(K),3) = TRPROW + 1
C      END OF REPEAT
C   END OF IF
C
C   IF PRTLVL = 0 WRITE OUT THE ORDERED TRIPLES
  100  IF (PRTLVL.NE.0) GO TO 600
       N = TRPROW
```

```
             DO 110 TRPROW = 1,N
      110       WRITE (6,510) (TRIPLE(TRPROW,J), J = 1, 3)
      C   END OF IF
      510       FORMAT (' ', T10, I7, T25, I7, T40, I7)
      600    RETURN
             END
      C$EJECT
```

```
      SUBROUTINE RELATE (INPNT, INPUT, REMBER, TRIPLE, TRPROW)
C
C  XXXXX XXXXX X       X   XXXXX XXXXX
C  X   X X     X      X X    X   X
C  XXXXX XXXX  X     X   X   X   XXXX
C  X  X  X     X     XXXXX   X   X
C  X   X XXXXX XXXXX X   X   X   XXXXX
C
C * * * * * * * * FUNCTION OF MODULE * * * * * * * *
C
C     RELATE SCANS THE INPUT STACK OF TOKENS AND CHANGES THOSE IN A
C     RELATIONAL EXPRESSION INTO ORDERED TRIPLES WHICH ARE OUTPUT IN
C     AN ARRAY.
C
C * * * * * * * * PROCEDURE FOLLOWED * * * * * * * *
C
C     INPUT RELATIONAL EXPRESSIONS ARE RESTRICTED TO THE FOLLOWING
C     FORMAT:  1.  OPTIONAL STRING OF UNARY PLUSES AND/OR MINUSES;
C              2.  CONSTANT OR VARIABLE IDENTIFIER;
C              3.  RELATIONAL OPERATER;
C              4.  OPTIONAL STRING OF UNARY PLUSES AND/OR MINUSES;
C              5.  CONSTANT OR VARIABLE IDENTIFIER.
C     UNARY PLUSES ARE DISREGARDED.  UNARY MINUSES ARE ACCUMULATED
C     AND, IF THERE ARE AN ODD NUMBER OF THEM, THE CONSTANT OR VARIABLE
C     TOKEN IS CHANGED TO A NEGATIVE VALUE.  THE FIRST CONSTANT OR
C     VARIABLE IS PLACED IN THE SECOND COLUMN OF THE TRIPLE ARRAY,
C     THE RELATIONAL OPERATOR IN THE FIRST COLUMN, AND THE SECOND
C     CONSTANT OR VARIALBE IN THE THIRD COLUMN.
C
C * * * * * * * * VARIABLE DECLARATIONS * * * * * * * *
C
C PARAMETERS
C
C     INPNT -INTEGER, POINTS TO TOKENS IN THE INPUT VECTOR
C     INPUT -INTEGER ARRAY, LENGTH 100, FOR PASSING TOKENS TO THIS
C            MODULE
C     REMBER-INTEGER, SAVES INTERNAL ADDRESS OF TRIPLE ARRAY TO INSERT
C            ADDRESS FROM BLDTRP SUBROUTINE
C     TRIPLE-INTEGER ARRAY, SIZE 80 BY 3, FOR RETURNING ORDERED TRIPLES
C     TRPROW-INTEGER, POINTER TO ROWS OF THE ARRAY OF ORDERED TRIPLES
C
      INTEGER INPNT, INPUT(100), REMBER, TRIPLE(80,3), TRPROW
C
C LOCAL VARIABLES
C
C     MINUS -INTEGER, UNARY MINUS OPERATOR TOKEN 50006
```

```
C     PLUS  -INTEGER, UNARY PLUS OPERATOR TOKEN 50005
C     POP   -INTEGER, OPERATOR WHICH MAY BE INSERTED INTO THE ORDERED
C                     TRIPLE ARRAY FOR POPPING RESULT FROM A STACK
C     RELOPS-INTEGER ARRAY, SIZE 2 BY 6, HOLDS RELATIONAL OPERATOR AND
C             BRANCH CODES. THE OPERATOR CODES INSERTED INTO THE ORDERED
C             TRIPLE ARRAY ARE:
C                   INPUT      RELATIONAL     BRANCH      BRANCH
C                   TOKEN       OPERATOR     CONDITION     CODE
C                   30001         .EQ.          BNZ        50011
C                   30002         .NE.          BZ         50012
C                   30003         .GT.          BMZ        50013
C                   30004         .LT.          BPZ        50014
C                   30005         .GE.          BM         50015
C                   30006         .LE.          BP         50016
C     RELPNT-INTEGER, POINTER TO ENTRIES IN RELOPS ARRAYY
C     TEMP  -INTEGER, USED FOR DETERMINING IF TOKEN IS A VARIABLE OR
C             CONSTANT
C     THEN  -INTEGER, POSSIBLE INPUT TOKEN 142408
C     UMINUS-INTEGER, UNARY MINUS MULTIPLYING FACTOR
C
      INTEGER MINUS, PLUS, POP, RELOPS(2,6), RELPNT, SUB, TEMP, THEN,
     &        UMINUS
      DATA   MINUS/50006/, PLUS/50005/, POP/50019/, RELOPS/30001, 50011,
     &     30002, 50012, 30003, 50013, 30004, 50014, 30005, 50015,
     &     30006, 50016/, SUB/50006/, THEN/142408/
C
C * * * * * * * * EXECUTABLE CODE * * * * * * * *
C
       UMINUS = +1
       INPNT = INPNT - 1
       TRPROW = TRPROW + 1
C
 10    CONTINUE
C   INCREMENT THE INPUT ARRAY POINTER
       INPNT = INPNT + 1
C   IF THE TOKEN IS UNARY PLUS DISREGARD AND GET THE NEXT TOKEN
       IF (INPUT(INPNT).EQ.PLUS) GO TO 10
C   END OF IF
C
C   IF TOKEN IS UNARY MINUS CHANGE THE SIGN OF THE UNARY MINUS FACTOR
       IF (INPUT(INPNT).NE.MINUS) GO TO 40
         UMINUS = - UMINUS
C      AND GET THE NEXT TOKEN
         GO TO 10
C   END OF IF
C
 40    CONTINUE
C   IF TOKEN IS A CONSTANT OR VARIABLE
       TEMP = INPUT(INPNT)/10000
       IF ((TEMP.NE.2).AND.((TEMP.LT.7).OR.(TEMP.GT.9)).AND.
     &   (TEMP.LT.13)) GO TO 400
```

```
C       THEN MULTIPLY BY UNARY MINUS FACTOR AND MOVE THE TOKEN TO
C          COLUMN TWO OF THE TRIPLE ARRAY
           TRIPLE(TRPROW,2) = INPUT(INPNT) * UMINUS
C    END OF IF
C
C    RESET UNARY MINUS FACTOR TO POSITIVE
        UMINUS = +1
C    GET THE NEXT TOKEN
        INPNT = INPNT + 1
C    PLACE SUBTRACT CODE IN COLUMN ONE OF TRIPLE ARRAY
        TRIPLE(TRPROW,1) = SUB
C
C    OBTAIN THE PROPER CODE FOR THE RELATIONAL OPERATOR
C       REPEAT
C          COMPARE INPUT TOKEN WITH RELATIONAL OPERATOR ARRAY
           DO 50 RELPNT = 1,6
              IF (INPUT(INPNT).EQ.RELOPS(1,RELPNT)) GO TO 60
 50     CONTINUE
C       END OF REPEAT
C
 60     CONTINUE
C    PLACE THE PROPER BRANCH CODE, BASED ON THE RELATIONAL OPERATOR,
C       IN COLUMN ONE OF THE NEXT TRIPLE ROW
        TRIPLE(TRPROW + 1, 1) = RELOPS(2,RELPNT)
C    PLACE 'POP' OPERATOR IN COLUMN TWO OF THE TRIPLE ARRAY
        TRIPLE(TRPROW + 1, 2) = POP
C    RETAIN THE TRIPLE ROW NUMBER FOR LATER INSERTION OF BRANCH ADDRESS
        REMBER = TRPROW + 1
 70     CONTINUE
        INPNT = INPNT + 1
C    IF THE TOKEN IS UNARY PLUS DISREGARD AND GET THE NEXT TOKEN
        IF (INPUT(INPNT).EQ.PLUS) GO TO 70
C    END OF IF
C
C    IF TOKEN IS UNARY MINUS CHANGE THE SIGN OF THE UNARY MINUS FACTOR
        IF (INPUT(INPNT).NE.MINUS) GO TO 90
           UMINUS = - UMINUS
C       AND GET THE NEXT TOKEN
           GO TO 70
C    END OF IF
C
 90     CONTINUE
C    IF TOKEN IS A CONSTANT OR VARIABLE
        TEMP = INPUT(INPNT)/10000
        IF ((TEMP.NE.2).AND.((TEMP.LT.7).OR.(TEMP.GT.9)).AND.
     &    (TEMP.LT.15)) GO TO 400
C       THEN MULTIPLY BY UNARY MINUS FACTOR AND MOVE THE TOKEN TO
C          COLUMN THREE OF THE TRIPLE ARRAY
           TRIPLE(TRPROW,3) = INPUT(INPNT) * UMINUS
           INPNT = INPNT + 1
           GO TO 500
```

```
C   END OF IF
C
400     CONTINUE
C   PRINT ERROR MESSAGE
        PRINT, 'ERROR--TOKEN NOT A CONSTANT OR VARIABLE. TOKEN = ',
      &    INPUT(INPNT)
        TRPROW = TRPROW + 1
        INPNT = INPNT + 1
500     CONTINUE
        TRPROW = TRPROW + 1
        RETURN
        END
C$EJECT
```

```
      SUBROUTINE POSTFX (BRADDR, NUMBX, INPNT, INPUT, OUTPUT,
     &           PRTLVL, REMBER, TRIPLE, TRPROW)
C
C  XXXXX XXXXX XXXXX XXXXX XXXXX X   X
C  X   X X   X X       X   X      X X
C  XXXXX X   X XXXXX   X   XXXX    X
C  X     X   X     X   X   X      X X
C  X     XXXXX XXXXX   X   X     X   X
C
C * * * * * * * * FUNCTION OF MODULE * * * * * * * *
C
C     POSTFX TAKES AN INFIX ASSIGNMENT CLAUSE AS INPUT AND CONVERTS
C     IT INTO AN EXPRESSION OF POSTFIX NOTATION WHICH IS OUTPUT.
C
C * * * * * * * * PROCEDURE FOLLOWED * * * * * * * *
C
C     IF THE TOKEN IS AN END DELIMITER OR A REMARK, THE TOKENS IN THE
C     STACK ARE OUTPUT UNTIL THE STACK IS EMPTY.  IF THE TOKEN IS '(',
C     IT IS PUSHED ONTO THE STACK.  IF THE TOKEN IS A MINUS SIGN A
C     CHECK IS MADE TO DETERMINE IF IT IS A UNARY MINUS.  IF IT IS
C     A UNARY MINUS, THE CONSTANT OR VARIABLE TOKEN ON WHICH IT
C     OPERATES IS CHANGED TO A NEGATIVE VALUE.
C     IF THE TOKEN IS A CONSTANT OR A VARIABLE, IT IS MOVED DIRECTLY
C     TO THE OUTPUT.  IF THE TOKEN IS AN OPERATOR AND THE STACK IS
C     EMPTY, IT IS PUSHED ONTO THE STACK.  IF THE STACK IS NOT EMPTY,
C     THE TOKEN IS COMPARED WITH THE TOKEN AT THE TOP OF THE STACK
C     AND IF THE STACK TOKEN IS OF EQUAL OR HIGHER PRECEDENCE IT IS
C     MOVED TO OUTPUT.  OTHERWISE IF THE TOKEN IS ')', BOTH IT AND
C     THE '(' FROM THE STACK ARE DISREGARDED.  FINALLY IF NONE OF THE
C     ABOVE CONDITIONS ARE TRUE, THE TOKEN IS PUSHED ONTO THE STACK
C     AND THE NEXT TOKEN IS FETCHED.  TOKEN ORDER-OF-PRECEDENCE FROM
C     LOWEST TO HIGHEST IS OPENING PARENTHESIS '(', CLOSINC PARENTHESIS
C     ')', PLUS OR MINUS SIGN '+ OR -', MULTIPLY OR DIVIDE '* OR /',
C     EXPODENTIATION '**', UNARY MINUS, AND FUNCTIONS.
C
C * * * * * * * * SUBROUTINES CALLED * * * * * * * *
C
C     BLDTRP-MOVES POSTFIX-ORDERED TOKENS INTO ARRAY OF ORDERED TRIPLES
C
C * * * * * * * * VARIABLE DECLARATIONS * * * * * * * *
C
C PARAMETERS
C
C     BRADDR-INTEGER ARRAY, LENGTH 20, HOLDS INTERNAL ADDRESS OF TRIPLE
C            ROWS WHICH WILL GET UNCONDITIONAL BRANCH TO END OF TRIPLS
C     NUMBX -INTEGER, COUNTS THE NUMBER OF PLACES FOR UNCONDITIONAL
C            BRANCH TO END OF TRIPLES, INCREMENTS THE BRADDR ARRAY
```

```
C     INPNT -INTEGER, POINTS TO TOKENS IN THE INPUT VECTOR
C     INPUT -INTEGER ARRAY, LENGTH 100, FOR PASSING TOKENS TO THIS
C            MODULE
C     OUTPUT-INTEGER ARRAY, LENGTH 100, FOR RETURNING POSTFIX
C            ARITHMEIC EXPRESSION
C     PRTLVL-INTEGER, VARIALBE TO ALLOW PRINTING OF EXTRA INFORMATION
C            WHICH SHOULD BE HELPFUL IN MODIFYING OR DEBUGGING THE
C            SYSTEM
C     REMBER-INTEGER, SAVES INTERNAL ADDRESS OF TRIPLE ARRAY TO INSERT
C            ADDRESS FROM BLDTRP SUBROUTINE
C     TRIPLE-INTEGER ARRAY, SIZE 80 BY 3, FOR RETURNING ORDERED TRIPLES
C     TRPROW-INTEGER, POINTER TO ROWS OF THE ARRAY OF ORDERED TRIPLES
C
      INTEGER BRADDR(20), INPNT, INPUT(100), NUMBX, OUTPUT(100),
     &       PRTLVL, REMBER, TRIPLE(80,3), TRPROW
C
C LOCAL VARIABLES
C
C     ARRPNT-INTEGER, POINTS TO ENTRIES IN THE PRECEDENCE ARRAY
C     CPAREN-INTEGER, POSSIBLE INPUT TOKEN OF CLOSING PARENTHESIS
C     ELSE  -INTEGER, POSSIBLE INPUT TOKEN 142409
C     MINUS -INTEGER, POSSIBLE INPUT TOKEN 50006
C     NOSAVE-INTEGER, POSSIBLE INPUT TOKEN 144002
C     OPAREN-INTEGER, POSSIBLE INPUT TOKEN OF OPENING PARENTHESIS
C     OUTPNT-INTEGER, POINTS TO TOKENS IN OUTPUT VECTOR
C     PLUS  -INTEGER, POSSIBLE INPUT TOKEN 50005
C     PREC  -INTEGER ARRAY, SIZE 2 BY 18, HOLDS PRECEDENCE OF
C            ARITHMETIC OPERATORS
C     PRECS -INTEGER, PRECEDENCE OF TOKEN AT TOP OF THE STACK
C     PRECT -INTEGER, PRECEDENCE OF TOKEN CURRENTLY UNDER CONSIDERATION
C     STACK -INTEGER ARRAY, LENGTH 30, STACK FOR PROCESSING OPERATORS
C     STKPNT-INTEGER, POINTER TO NEXT EMPTY POSITION ON THE STACK
C     TEMP  -INTEGER, USED FOR DETERMINING IF TOKEN IS A VARIABLE OR
C            CONSTANT
C     THEN  -INTEGER, POSSIBLE INPUT TOKEN 142408
C     UMINUS-INTEGER, UNARY MINUS MULTIPLYING FACTOR
C
      INTEGER ARRPNT, CPAREN, ELSE, END, IF, MINUS, OPAREN, OUTPNT,
     &       PLUS, PREC(2,18), PRECS, PRECT, STACK(30), STKPNT, TEMP,
     &       THEN, UMINUS
      DATA   CPAREN/50004/, ELSE/142409/, END/50030/, IF/140805/,
     &       MINUS/50006/, NOSAVE/144002/, OPAREN/50003/, PLUS/50005/,
     &       THEN/142408/
      DATA   PREC/50003, 0, 50004, 1, 50005, 3, 50006, 3, 50007, 4,
     & 50008, 4, 50009, 5, 50010, 2, 60001, 7, 60002, 7, 60003, 7,
     & 60004, 7, 60005, 7, 60006, 7, 60007, 7, 60008, 7, 60009, 7,
     & 60010, 7/
C
C * * * * * * * * EXECUTABLE CODE * * * * * * * *
C
       OUTPNT = 1
```

```
                 STKPNT = 1
                 UMINUS = +1
          C   IF THE TOKEN IS "THEN" OR "ELSE" MOVE IT TO OUTPUT
                 IF ((INPUT(INPNT).NE.THEN).AND.(INPUT(INPNT).NE.ELSE)) GO TO 10
                    OUTPUT(OUTPNT) = INPUT(INPNT)
                    OUTPNT = OUTPNT + 1
                    GO TO 20
          C   END OF IF
          C
           10    CONTINUE
                 INPNT = INPNT - 1
           20    CONTINUE
          C   INCREMENT THE INPUT ARRAY POINTER
                 INPNT = INPNT + 1
          C
          C   IF THE TOKEN DELIMITS THE ASSIGNMENT CLAUSE (NOSAVE, IF, ELSE,
          C      OR REMARK)
                 IF ((INPUT(INPNT).NE.NOSAVE).AND.(INPUT(INPNT).NE.140805).AND.
               &  (INPUT(INPNT).NE.ELSE).AND.((INPUT(INPNT)/10000).NE.1)) GO TO 40
          C      THEN
          C         WHILE THE STACK IS NOT EMPTY
           30          CONTINUE
                          IF (STKPNT.EQ.1) GO TO 500
                          STKPNT = STKPNT - 1
          C            MOVE STACK TO OUTPUT
                          OUTPUT(OUTPNT) = STACK(STKPNT)
                          OUTPNT = OUTPNT + 1
                          GO TO 30
          C      END OF WHILE
          C   END OF IF.
          C
           40    CONTINUE
          C   IF THE TOKEN = '(',
                 IF (INPUT(INPNT).NE.OPAREN) GO TO 50
          C      THEN PUSH TOKEN ONTO STACK
                    STACK(STKPNT) = INPUT(INPNT)
                    STKPNT = STKPNT + 1
                    GO TO 20
          C   END OF IF.
          C
           50    CONTINUE
          C   IF TOKEN IS A CONSTANT OR VARIABLE
                 TEMP = INPUT(INPNT)/10000
                 IF ((TEMP.NE.2).AND.((TEMP.LT.7).OR.(TEMP.GT.9))
               &          .AND.(TEMP.LT.15)) GO TO 60
          C      THEN MULTIPLY BY UNARY MINUS FACTOR AND MOVE TOKEN TO OUTPUT
                    OUTPUT(OUTPNT) = INPUT(INPNT)*UMINUS
          C      RESET UNARY MINUS FACTOR TO POSITIVE
                    UMINUS = +1
                    OUTPNT = OUTPNT + 1
                    GO TO 20
```

```
C   END OF IF.
C
 60    CONTINUE
C   IF TOKEN IS '+' OR '-'
       IF((INPUT(INPNT).NE.PLUS).AND.(INPUT(INPNT).NE.MINUS)) GO TO 80
C      THEN IF THIS IS THE FIRST TOKEN OF THIS ASSIGNMENT CLAUSE
C         THEN TOKEN IS A UNARY MINUS OR UNARY PLUS
          IF (INPNT.EQ.1) GO TO 70
C      END OF IF.
C         ELSE IF PREVIOUS TOKEN IS A FUNCTION OR OPERATOR BUT NOT ')'
C            THEN TOKEN IS A UNARY MINUS OR UNAPY PLUS
             TEMP = INPUT(INPNT - 1)/10000
             IF (((TEMP.NE.5).AND.(TEMP.NE.6)).OR.
     &          (INPUT(INPNT-1).EQ.CPAREN)) GO TO 80
C         END OF IF.
C   END OF IF.
 70    CONTINUE
C
C   IF TOKEN IS UNARY PLUS DISREGARD AND GET NEXT TOKEN
          IF (INPUT(INPNT).EQ.PLUS) GO TO 20
C   END OF IF
C   IF TOKEN IS UNARY MINUS CHANGE SIGN OF UNARY MINUS FACTOR
          UMINUS = -UMINUS
C      RETURN FOR NEXT TOKEN
          GO TO 20
C   END OF IF.
C
 80    CONTINUE
C   IF STACK IS EMPTY
       IF (STKPNT.NE.1) GO TO 90
C      THEN PUSH TOKEN ONTO STACK
          STACK(STKPNT) = INPUT(INPNT)
          STKPNT = STKPNT + 1
          GO TO 20
C   END OF IF.
C
 90    CONTINUE
C   ASSIGN PRECEDENCE OF OPERATOR AT TOP OF STACK TO 'PRECS'
C   REPEAT
C      COMPARE TOKEN AT TOP OF STACK WITH PRECEDENCE ARRAY
       DO 100 ARRPNT = 1,18
100       IF (STACK(STKPNT - 1).EQ.PREC(1,ARRPNT)) GO TO 110
C   END OF REPEAT.
110    PRECS = PREC(2,ARRPNT)
C
C   ASSIGN PRECEDENCE OF OPERATOR CURRENTLY UNDER CONSIDERATION TO
C      'PRECT'
C   REPEAT
C      COMPARE INPUT TOKEN WITH PRECEDENCE ARRAY
       DO 120 ARRPNT = 1,18
120       IF (INPUT(INPNT).EQ.PREC(1,ARRPNT)) GO TO 130
```

```
C   END OF REPEAT.
130        PRECT = PREC(2,ARRPNT)
C
C   COMPARE PRECEDENCE OF TOKEN AT TOP OF STACK WITH INPUT TOKEN
C   IF PRECS > OR = PRECT
           IF (PRECS.LT.PRECT) GO TO 140
C      THEN MOVE TOP OF STACK OPERATOR TO OUTPUT AND COMPARE TOKEN
C               OPERATOR TO NEXT OPERATOR IN STACK.
           STKPNT = STKPNT - 1
           OUTPUT(OUTPNT) = STACK(STKPNT)
           OUTPNT = OUTPNT + 1
           GO TO 80
140    CONTINUE
C      ELSE IF TOKEN = ')'
           IF (INPUT(INPNT).NE.CPAREN) GO TO 150
C      DISREGARD BOTH THE TOKEN AND '(', AND GET NEXT INPUT TOKEN
           STKPNT = STKPNT - 1
           GO TO 20
C      END OF IF.
150    CONTINUE
C      ELSE PUSH TOKEN ONTO STACK
           STACK(STKPNT) = INPUT(INPNT)
           STKPNT = STKPNT + 1
           GO TO 20
C   END OF IF.
C
500    CONTINUE
C   PLACE AN IDENTIFIALBE DELIMITER ONTO THE STACK
       OUTPUT(OUTPNT) = END
C
C   IF PRTLVL = 0 WRITE OUT THE POSTFIX ASSIGNMENT CLAUSE
       IF (PRTLVL.EQ.0) WRITE (6,505) (OUTPUT(I), I = 1, OUTPNT)
C   END OF IF
C
       CALL BLDTRP (BRADDR, NUMBX, OUTPNT, OUTPUT, REMBER, TRIPLE,
     &     TRPROW)
505        FORMAT (' ', 16(I7, 1X))
       RETURN
       END
C$EJECT
```

```
       SUBROUTINE BLDTRP (BRADDR, NUMBX, OUTPNT, OUTPUT, REMBER, TRIPLE,
     &    TRPROW)
C
C  XXXX  X     XXXX  XXXXX XXXXX XXXXX
C  X   X X     X   X   X   X   X X   X
C  XXXX  X     X   X   X   XXXXX XXXXX
C  X   X X     X   X   X   X   X X
C  XXXX  XXXXX XXXX    X   X   X X
C
C * * * * * * * * FUNCTION OF MODULE * * * * * * * *
C
C     BLDTRP ACCEPTS THE VECTOR OF ASSIGNMENT CLAUSE TOKENS WHICH ARE
C     IN POSTFIX ORDER AS INPUT AND PROCESSES THEM INTO AN ARRAY OF
C     ORDERED TRIPLES WHICH ARE OUTPUT.
C
C * * * * * * * * PROCEDURE FOLLOWED * * * * * * * *
C
C     THE VECTOR OF ASSIGNMENT CLAUSE TOKENS IS PARSED UNTIL AN
C     OPERATOR IS FOUND WHICH IS PLACED IN THE FIRST COLUMN OF THE
C     ARRAY OF ORDERED TRIPLES.  THEN THE MODULE BACKSPACES IN THE
C     ASSIGNMENT CLAUSE VECTOR TO FIND THE OPERAND(S) FOR THAT
C     OPERATOR.  ONE OPERAND IS REQUIRED FOR FUNCTION OPERATORS AND
C     TWO OPERANDS FOR THE COMMON BINARY OPERATORS.  THE OPERAND(S)
C     ARE PLACED IN THE SECOND AND THIRD COLUMNS OF THE ORDERED
C     TRIPLE ARRAY.  THE INPUT VECTOR POSITION OF THE OPERAND OF
C     UNARY OPERATORS AND THE SECOND OPERAND OF BINARY OPERATORS ARE
C     REPLACED WITH THE 'POP' OPERATOR (113) WHICH WILL POP THE TOP
C     INTERIM RESULT FROM A STACK DURING EXECUTION.  THE INPUT VECTOR
C     LOCATION OF OPERATORS AND FIRST OPERAND OF THE BINARY OPERATORS
C     ARE ASSIGNED A VALUE OF ZERO TO INDICATE THE OPERATOR OR OPERAND
C     HAS BEEN MOVED TO THE TRIPLE ARRAY.  THE ARRAY OF ORDERED
C     TRIPLES IS RETURNED TO THE CALLING MODULE.
C
C * * * * * * * * VARIABLE DECLARATIONS * * * * * * * *
C
C PARAMETERS
C
C     BRADDR-INTEGER ARRAY, LENGTH 20, HOLDS INTERNAL ADDRESS OF TRIPLE
C            ROWS WHICH WILL GET UNCONDITIONAL BRANCH TO END OF TRIPLES
C     NUMBX -INTEGER, COUNTS THE NUMBER OF PLACES FOR UNCONDITIONAL
C            BRANCH TO END OF TRIPLES, INCREMENTS THE BRADDR ARRAY
C     OUTPNT-INTEGER, BRINGS IN POINTER TO LAST TOKEN IN OUTPUT VECTOR;
C            ALSO USED AS POINTER IN OUTPUT VECTOR
C     OUTPUT-INTEGER ARRAY, LENGTH 100, FOR PASSING POSTFIX
C            ASSIGNMENT CLAUSE
C     REMBER-INTEGER, SAVES INTERNAL ADDRESS OF TRIPLE ARRAY TO INSERT
```

```
C            ADDRESS FROM BLDTRP SUBROUTINE
C      TRIPLE-INTEGER ARRAY, SIZE 80 BY 3, FOR RETURNING ORDERED TRIPLES
C      TRPROW-INTEGER, POINTER TO ROWS OF THE ARRAY OF ORDERED TRIPLES
C
       INTEGER BRADDR(20), NUMBX, OUTPNT, OUTPUT(100), REMBER,
     &         TRIPLE(80,3), TRPROW
C
C LOCAL VARIABLES
C
C      BEGIN -INTEGER, KEEPS POSITION IN OUTPUT VECTOR WHERE LAST
C            OPERAND WAS FOUND
C      END   -INTEGER, DELIMITER FOR POSTFIX STACK
C      POP   -INTEGER, OPERATOR TO POP THE TOP INTERIM ORDERED TRIPLE
C            RESULT FROM A STACK
C      STAKLN-INTEGER, STORES LENGTH OF THE POSTFIX STACK
C      TEMP  -INTEGER, USED FOR DETERMINING IF TOKEN IS A VARIABLE OR
C            CONSTANT
C
       INTEGER BEGIN, BRANCH, END, POP, STAKLN, TEMP
       DATA  BRANCH/50017/, END/50030/, POP/50019/
C
C * * * * * * * * EXECUTABLE CODE * * * * * * * *
C
        STAKLN = OUTPNT
        BEGIN = 1
        OUTPNT = 1
C
 10     CONTINUE
C   REPEAT
C       WHILE THE TOKEN IS NOT THE 'END' DELIMITER
           IF (OUTPUT(OUTPNT).EQ.END) GO TO 500
C          DO PARSE THE TOKENS, MOVING OPERATORS AND OPERANDS INTO THE
C             PROPER PLACE IN THE ARRAY OF ORDERED TRIPLES
C
C       REPEAT
C          PARSE THE POSTFIX VECTOR UNTIL AN OPERATOR IS FOUND
C             STARTING WHERE LAST OPERAND WAS FOUND
           DO 30 OUTPNT = BEGIN, STAKLN
C          IF POSTFIX STACK DELIMITER IS ENCOUNTERED, STOP SUBROUTINE
              IF (OUTPUT(OUTPNT).EQ.END) GO TO 500
C          END OF IF
              TEMP = OUTPUT(OUTPNT)/10000
              IF ((TEMP.EQ.5).OR.(TEMP.EQ.6)) GO TO 40
 30        CONTINUE
C       END OF REPEAT
C
 40        BEGIN = OUTPNT + 1
           TRPROW = TRPROW + 1
C       PLACE OPERATOR FOUND IN FIRST COLUMN OF THE TRIPLE ARRAY
           TRIPLE(TRPROW,1) = OUTPUT(OUTPNT)
C       BLANK OUT THE POSITION OF THE OPERATOR TOKEN IN THE POSTFIX ARRAY
```

```
               OUTPUT(OUTPNT) = 0
      C      REPEAT
      C         BACKSPACE IN OUTPUT VECTOR UNTIL OPERAND OR PREVIOUS TRIPLE
      C            INTERIM RESULT IS FOUND
                   DO 50 I = 1, STAKLN
                      OUTPNT = OUTPNT - 1
                      TEMP = IABS(OUTPUT(OUTPNT)/10000)
                      IF ((TEMP.EQ. 2).OR.((TEMP.GE.7).AND.(TEMP.LE.9)).OR.
           &              (TEMP.GE.15).OR.(OUTPUT(OUTPNT).EQ.POP)) GO TO 70
       50          CONTINUE
      C      END OF REPEAT
      C
       70    CONTINUE
      C      PLACE FIRST OPERAND IN THIRD COLUMN OF TRIPLE ARRAY
                TRIPLE(TRPROW,3) = OUTPUT(OUTPNT)
      C      STORE 'POP' OPERATOR IN THE POSTFIX STRING
                OUTPUT(OUTPNT) = POP
      C      IF OPERATOR WAS A UNARY OPERATOR (FUNCTION), THEN GET NEXT TOKEN
                IF ((TRIPLE(TRPROW,1))/10000.EQ.6) GO TO 10
      C         ELSE GET THE SECOND OPERAND
      C         REPEAT
      C            BACKSPACE IN OUTPUT VECTOR UNTIL OPERAND OR PREVIOUS TRIPLE
      C               INTERIM RESULT IS FOUND
                      DO 90 I = 1, STAKLN
                         OUTPNT = OUTPNT - 1
                         TEMP = IABS(OUTPUT(OUTPNT)/10000)
                         IF ((TEMP.EQ. 2).OR.((TEMP.GE.7).AND.(TEMP.LE.9)).OR.
           &                 (TEMP.GE.15).OR.(OUTPUT(OUTPNT).EQ.POP)) GO TO 100
       90             CONTINUE
      C         END OF REPEAT
      C      END OF IF
      C
      100       CONTINUE
      C         PLACE SECOND OPERAND IN SECOND COLUMN OF TRIPLE ARRAY
                   TRIPLE(TRPROW,2) = OUTPUT(OUTPNT)
      C         BLANK OUT THE POSITION OF THE OPERAND TOKEN IN POSTFIX STRING
                   OUTPUT(OUTPNT) = 0
      C         END OF IF
      C      GET THE NEXT TOKEN
             GO TO 10
      C   END OF REPEAT WHILE
      C
      500    CONTINUE
      C   IF A RELATIONAL EXPRESSION EXISTS IN THE ORDERED TRIPLES
             IF (REMBER.EQ.0) GO TO 600
      C      THEN INSERT THE ADDRESS OF THE NEXT TRIPLE ROW AS THE ADDRESS OF
      C         THE CONDITIONAL BRANCH ASSOCIATED WITH THE RELATIONAL
      C         EXPRESSION.
                TRIPLE(REMBER,3) = TRPROW + 2
      C      ZERO OUT PARAMETER
                REMBER = 0
```

```
                TRPROW = TRPROW + 1
      C      INSERT UNCONDITIONAL BRANCH OPERATOR INTO ORDERED TRIPLES
      C      (THE ADDRESS OF THIS BRANCH IS INSERTED IN SUBROUTINE CTRIPS)
                TRIPLE(TRPROW,1) = BRANCH
      C      INCREMENT THE NUMBER OF TIMES AN UNCONDITIONAL BRANCH ADDRESS
      C         HAS BEEN SAVED
                NUMBX = NUMBX + 1
      C      SAVE THE INTERNAL TRIPLE ADDRESS FOR USE IN CTRIPS SUBROUTINE
                BRADDR(NUMBX) = TRPROW
      C   END OF IF
      C
      600    RETURN
             END
      C$EJECT
```

```
      SUBROUTINE PSTFXS (INPUT, PRTLVL, TRIPLE, TRPROW)
C
C  XXXXX XXXXX XXXXX XXXXX X   X XXXXX
C  X   X X       X   X      X X  X
C  XXXXX XXXXX   X   XXXX    X   XXXXX
C  X         X   X   X      X X      X
C  X     XXXXX   X   X     X   X XXXXX
C
C * * * * * * * * FUNCTION OF MODULE * * * * * * * *
C
C     PSTFXS TAKES A BOOLEAN EXPRESSION COMPOSED OF LOGICAL OPERATORS
C     WITH RELATIONAL EXPRESSION OPERANDS AS INPUT AND CONVERTS THEM
C     INTO POSTFIX NOTATION WHICH IS OUTPUT.
C
C * * * * * * * * PROCEDURE FOLLOWED * * * * * * * *
C
C     IF THE TOKEN IS AN END DELIMITER OR A REMARK, THE TOKENS IN THE
C     STACK ARE OUTPUT UNTIL THE STACK IS EMPTY.  IF THE TOKEN IS '(',
C     IT IS PUSHED ONTO THE STACK.  IF THE TOKEN IS A MINUS SIGN A
C     CHECK IS MADE TO DETERMINE IF IT IS A UNARY MINUS.  IF IT IS
C     A UNARY MINUS, THE CONSTANT OR VARIABLE TOKEN ON WHICH IT
C     OPERATES IS CHANGED TO A NEGATIVE VALUE.  IF THE TOKEN IS AN
C     OPERAND (OR PORTION OF AN OPERAND) OF A LOGICAL OPERATOR (.AND.,
C     .OR.) TO THE OUTPUT.  IF THE TOKEN IS AN OPERATOR AND THE STACK IS
C     EMPTY, IT IS PUSHED ONTO THE STACK.  IF THE STACK IS NOT EMPTY,
C     THE TOKEN IS COMPARED WITH THE TOKEN AT THE TOP OF THE STACK
C     AND IF THE STACK TOKEN IS OF EQUAL OR HIGHER PRECEDENCE IT IS
C     MOVED TO OUTPUT.  OTHERWISE IF THE TOKEN IS ')', BOTH IT AND
C     THE '(' FROM THE STACK ARE DISREGARDED.  FINALLY IF NONE OF THE
C     ABOVE CONDITIONS ARE TRUE, THE TOKEN IS PUSHED ONTO THE STACK
C     AND THE NEXT OPERATOR FETCHED.  OPERATOR ORDER-OF-PRECEDENCE FROM
C     LOWEST TO HIGHEST IS OPENING PARENTHESIS '(', CLOSING PARENTHESIS
C     ')', LOGICAL OR '.OR.', AND LOGICAL AND '.AND.'.
C
C * * * * * * * * SUBROUTINES CALLED * * * * * * * *
C
C     TRIPLS-MOVES POSTFIX-ORDERED TOKENS INTO ARRAY OF ORDERED TRIPLES
C
C * * * * * * * * VARIABLE DECLARATIONS * * * * * * * *
C
C PARAMETERS
C
C     INPUT -INTEGER ARRAY, LENGTH 100, FOR PASSING TOKENS TO THIS
C            MODULE
C     PRTLVL-INTEGER, VARIALBE TO ALLOW PRINTING OF EXTRA INFORMATION
C            WHICH SHOULD BE HELPFUL IN MODIFYING OR DEBUGGING THE
```

```
C           SYSTEM
C     TRIPLE-INTEGER ARRAY, SIZE 80 BY 3, FOR RETURNING ORDERED TRIPLES
C     TRPROW-INTEGER, POINTER TO ROWS OF THE ARRAY OF ORDERED TRIPLES
C
      INTEGER INPUT(100), PRTLVL, TRIPLE(80,3), TRPROW
C
C LOCAL VARIABLES
C
C     ARRPNT-INTEGER, POINTS TO ENTRIES IN THE PRECEDENCE ARRAY
C     CPAREN-INTEGER, POSSIBLE INPUT TOKEN OF CLOSING PARENTHESIS
C     IN    -INTEGER, POSSIBLE INPUT TOKEN 140806
C     INPNT -INTEGER, POINTS TO TOKENS IN THE INPUT VECTOR
C     MINUS -INTEGER, POSSIBLE INPUT TOKEN 50006
C     NOSAVE-INTEGER, POSSIBLE INPUT TOKEN 144002
C     NOT   -INTEGER, POSSIBLE INPUT TOKEN 141607
C     OPAREN-INTEGER, POSSIBLE INPUT TOKEN OF OPENING PARENTHESIS
C     OUTPNT-INTEGER, POINTS TO TOKENS IN OUTPUT VECTOR
C     OUTPUT-INTEGER ARRAY, LENGTH 100, FOR PASSING POSTFIX
C           BOOLEAN EXPRESSION
C     PLUS  -INTEGER, POSSIBLE INPUT TOKEN 50005
C     PREC  -INTEGER ARRAY, SIZE 2 BY 4, HOLDS PRECEDENCE OF
C           ARITHMETIC OPERATORS
C     PRECS -INTEGER, PRECEDENCE OF TOKEN AT TOP OF THE STACK
C     PRECT -INTEGER, PRECEDENCE OF TOKEN CURRENTLY UNDER CONSIDERATION
C     STACK -INTEGER ARRAY, LENGTH 30, STACK FOR PROCESSING OPERATORS
C     STKPNT-INTEGER, POINTER TO NEXT EMPTY POSITION ON THE STACK
C     TEMP  -INTEGER, USED FOR DETERMINING IF TOKEN IS A VARIABLE OR
C           CONSTANT
C     UMINUS-INTEGER, UNARY MINUS MULTIPLYING FACTOR
C
      INTEGER ARRPNT, CPAREN, END, IN, INPNT, MINUS, NOSAVE, NOT,
     &      OPAREN, OUTPNT, OUTPUT(100), PLUS, PREC(2,4), PRECS, PRECT,
     &      STACK(30), STKPNT, TEMP, UMINUS
C
C CONSTANTS
C
      DATA  CPAREN/50004/, END/50030/, IN/140806/, MINUS/50006/,
     &      NOSAVE/144002/, NOT/141607/, OPAREN/50003/, PLUS/50005/,
     &      PREC/50003, 0, 50004, 1, 40001, 9, 40002, 8/
C
C * * * * * * * * EXECUTABLE CODE * * * * * * * *
C
       INPNT = 0
       OUTPNT = 1
       STKPNT = 1
       UMINUS = +1
C
 20    CONTINUE
C   INCREMENT THE INPUT ARRAY POINTER
       INPNT = INPNT + 1
C
```

```
C   IF THE TOKEN DELIMITS THE BOOLEAN EXPRESSION (NOSAVE, REMARK)
      IF ((INPUT(INPNT).NE.NOSAVE).AND.
     &   ((INPUT(INPNT)/10000).NE.1)) GO TO 40
C     THEN
C        WHILE THE STACK IS NOT EMPTY
            DO 30 I = 1,30
               IF (STKPNT.EQ.1) GO TO 500
               STKPNT = STKPNT - 1
C           MOVE STACK TO OUTPUT
               OUTPUT(OUTPNT) = STACK(STKPNT)
 30            OUTPNT = OUTPNT + 1
C     END OF WHILE
C   END OF IF.
C
 40   CONTINUE
C   IF THE TOKEN = '(',
      IF (INPUT(INPNT).NE.OPAREN) GO TO 50
C     THEN PUSH TOKEN ONTO STACK
         STACK(STKPNT) = INPUT(INPNT)
         STKPNT = STKPNT + 1
         GO TO 20
C   END OF IF.
C
 50   CONTINUE
C   IF THE TOKEN IS AN OPERAND (OR PORTION OF AN OPERAND) OF A LOGICAL
C     OPERATOR (CONSTANT, VARIABLE, IN, NOT, OR A RELATIONAL OPERATOR)
      TEMP = INPUT(INPNT)/10000
      IF (((INPUT(INPNT)/10000).EQ.4).OR.(INPUT(INPNT).EQ.CPAREN)
     &   .OR.(INPUT(INPNT).EQ.MINUS).OR.(INPUT(INPNT).EQ.PLUS)
     &   .OR.(INPUT(INPNT).EQ.OPAREN)) GO TO 60
C     THEN MOVE TOKEN TO OUTPUT
         OUTPUT(OUTPNT) = INPUT(INPNT) * UMINUS
C   END OF IF
C   RESET UNARY MINUS FACTOR TO POSITIVE
      UMINUS = +1
      OUTPNT = OUTPNT + 1
      GO TO 20
C
C   IF TOKEN IS '+' OR '-'
 60   CONTINUE
      IF((INPUT(INPNT).NE.PLUS).AND.(INPUT(INPNT).NE.MINUS)) GO TO 80
C     THEN IF THIS IS THE FIRST TOKEN OF THIS RELATIONAL EXPRESSION
C        THEN TOKEN IS A UNARY MINUS OR UNARY PLUS
         IF (INPNT.EQ.1) GO TO 70
C     END OF IF.
C        ELSE IF PREVIOUS TOKEN IS A FUNCTION OR OPERATOR BUT NOT ')'
C           THEN TOKEN IS A UNARY MINUS OR UNARY PLUS
            TEMP = INPUT(INPNT - 1)/10000
            IF (((TEMP.NE.5).AND.(TEMP.NE.6)).OR.
     &         (INPUT(INPNT-1).EQ.CPAREN)) GO TO 80
C        END OF IF.
```

```
      C   END OF IF.
      C
       70    CONTINUE
      C   IF TOKEN IS UNARY PLUS DISREGARD AND GET NEXT TOKEN
                IF (INPUT(INPNT).EQ.PLUS) GO TO 20
      C   END OF IF
      C   IF TOKEN IS UNARY MINUS CHANGE SIGN OF UNARY MINUS FACTOR
                UMINUS = -UMINUS
      C   RETURN FOR NEXT TOKEN
                GO TO 20
      C   END OF IF.
      C
       80    CONTINUE
      C   IF STACK IS EMPTY
             IF (STKPNT.NE.1) GO TO 90
      C   THEN PUSH TOKEN ONTO STACK
             STACK(STKPNT) = INPUT(INPNT)
             STKPNT = STKPNT + 1
             GO TO 20
      C   END OF IF.
      C
       90     CONTINUE
      C   ASSIGN PRECEDENCE OF OPERATOR AT TOP OF STACK TO 'PRECS'
      C   REPEAT
      C      COMPARE TOKEN AT TOP OF STACK WITH PRECEDENCE ARRAY
             DO 100 ARRPNT = 1,4
      100       IF (STACK(STKPNT - 1).EQ.PREC(1,ARRPNT)) GO TO 110
      C   END OF REPEAT.
      110    PRECS = PREC(2,ARRPNT)
      C
      C   ASSIGN PRECEDENCE OF OPERATOR CURRENTLY UNDER CONSIDERATION TO
      C      'PRECT'
      C   REPEAT
      C      COMPARE INPUT TOKEN WITH PRECEDENCE ARRAY
             DO 120 ARRPNT = 1,4
                IF (INPUT(INPNT).EQ.PREC(1,ARRPNT)) GO TO 130
      120       CONTINUE
      C   END OF REPEAT.
      130       PRECT = PREC(2,ARRPNT)
      C
      C   COMPARE PRECEDENCE OF TOKEN AT TOP OF STACK WITH INPUT TOKEN
      C   IF PRECS >= PRECT
                IF (PRECS.LT.PRECT) GO TO 140
      C      THEN MOVE TOP OF STACK OPERATOR TO OUTPUT AND COMPARE TOKEN
      C               OPERATOR TO NEXT OPERATOR IN STACK.
                STKPNT = STKPNT - 1
                OUTPUT(OUTPNT) = STACK(STKPNT)
                OUTPNT = OUTPNT + 1
                GO TO 80
      140       CONTINUE
      C      ELSE IF TOKEN = ')'
```

```
                IF (INPUT(INPNT).NE.CPAREN) GO TO 150
C           THEN DISREGARD BOTH THE TOKEN AND '(', AND GET NEXT TOKEN
                   STKPNT = STKPNT - 1
                   GO TO 20
150             CONTINUE
C           ELSE PUSH TOKEN ONTO STACK
                STACK(STKPNT) = INPUT(INPNT)
                STKPNT = STKPNT + 1
                GO TO 20
C        END OF IF.
C     END OF IF.
C
500      CONTINUE
C     PLACE AN IDENTIFIALBE DELIMITER ONTO THE STACK
         OUTPUT(OUTPNT) = END
C
C     IF PRTLVL = 0 WRITE OUT THE POSTFIX BOOLEAN EXPRESSION
         IF (PRTLVL.EQ.0) WRITE (6,505) (OUTPUT(I), I = 1, OUTPNT)
C     END OF IF
C
505         FORMAT (' ', 16(I7, 1X))
         CALL TRIPLS (OUTPNT, OUTPUT, PRTLVL, TRIPLE, TRPROW)
         RETURN
         END
```

```
      SUBROUTINE TRIPLS (OUTPNT, OUTPUT, PRTLVL, TRIPLE, TRPROW)
C
C  XXXXX XXXXX XXX XXXXX X     XXXXX
C    X   X   X  X  X   X X     X
C    X   XXXXX  X  XXXXX X     XXXXX
C    X   X  X   X  X     X         X
C    X   X   X XXX X     XXXXX XXXXX
C
C * * * * * * * * FUNCTION OF MODULE * * * * * * * *
C
C     TRIPLS ACCEPTS THE VECTOR OF BOOLEAN EXPRESSION TOKENS WHICH ARE
C     IN POSTFIX ORDER AS INPUT AND PROCESSES THEM INTO AN ARRAY OF
C     ORDERED TRIPLES WHICH ARE OUTPUT.
C
C * * * * * * * * PROCEDURE FOLLOWED * * * * * * * *
C
C     THE VECTOR OF BOOLEAN EXPRESSION TOKENS IS PARSED AND THE
C     TOKENS IDENTIFIED.  LOGICAL OPERATORS (.AND., .OR.) ARE MOVED
C     TO COLUMN ONE OF THE TRIPLE ARRAY.  THE OPERANDS 'IN GROUP/
C     MODULE' OR 'NOT IN GFOUP/MODULE' ARE MOVED DIRECTLY TO A TRIPLE.
C     THE OPERANDS OF RELATIONAL EXPRESSIONS ARE PLACED IN COLUMNS TWO
C     AND THREE OF THE TRIPLE WITH THE 'SUB' COMMAND IN COLUMN ONE.
C     A CONDITIONAL AND UNCONDITIONAL BRANCH ARE PLACED IN THE TRIPLES
C     TO CAUSE A '1' TO BE PUSHED ONTO THE STACK IF THE RELATIONAL
C     EXPRESSION IS TRUE OR A '0' IF IT IS FALSE.  THE FINAL TRIPLE
C     IS GIVEN THE COMMAND 'SETMSK' WHICH WILL POP THE FINAL RESULT
C     OF THE BOOLEAN EXPRESSION FROM THE STACK AND SET A MASK TO '1'
C     IF TRUE OR '0' IF FALSE.  THE ARRAY OF ORDERED TRIPLES IS
C     RETURNED TO THE CALLING MODULE.
C
C * * * * * * * * VARIABLE DECLARATIONS * * * * * * * *
C
C PARAMETERS
C
C     OUTPNT-INTEGER, BRINGS IN POINTER TO LAST TOKEN IN OUTPUT VECTOR;
C            ALSO USED AS POINTER IN OUTPUT VECTOR
C     OUTPUT-INTEGER ARRAY, LENGTH 100, FOR PASSING POSTFIX
C            BOOLEAN EXPRESSION
C     PRTLVL-INTEGER, VARIALBE TO ALLOW PRINTING OF EXTRA INFORMATION
C            WHICH SHOULD BE HELPFUL IN MODIFYING OR DEBUGGING THE
C            SYSTEM
C     TRIPLE-INTEGER ARRAY, SIZE 80 BY 3, FOR RETURNING ORDERED TRIPLES
C     TRPROW-INTEGER, POINTER TO ROWS OF THE ARRAY OF ORDERED TRIPLES
C
      INTEGER OUTPNT, OUTPUT(100), PRTLVL, TRIPLE(80,3), TRPROW
C
```

```
C LOCAL VARIABLES
C
C     BEGIN -INTEGER, KEEPS POSITION IN OUTPUT VECTOR WHERE LAST
C            OPERAND WAS FOUND
C     END   -INTEGER, DELIMITER FOR POSTFIX STACK
C     NOT   -INTEGER, POSSIBLE INPUT TOKEN 141607
C     POP   -INTEGER, OPERATOR TO POP THE TOP INTERIM ORDERED TRIPLE
C            RESULT FROM A STACK
C     RELOPS-INTEGER ARRAY, SIZE 2 BY 6, HOLDS RELATIONAL OPERATOR AND
C            BRANCH CODES. THE OPERATOR CODES INSERTED INTO THE ORDERED
C            TRIPLE ARRAY ARE:
C                  INPUT      RELATIONAL     BRANCH      BRANCH
C                  TOKEN       OPERATOR    CONDITION      CODE
C                  30001         .EQ.         BNZ        50011
C                  30002         .NE.         BZ         50012
C                  30003         .GT.         BMZ        50013
C                  30004         .LT.         BPZ        50014
C                  30005         .GE.         BP         50015
C                  30006         .LE.         BM         50016
C     SAVE  -INTEGER, SAVE THE ADDRESS OF OPERAND OF LOGICAL OPERATOR
C     TEMP  -INTEGER, USED FOR DETERMINING IF TOKEN IS A VARIABLE OR
C            CONSTANT
C
      INTEGER ADD, AND, BEGIN/1/, BNZ, BRANCH, BOOLOP, END, OR, POP,
     &     RELOPS(2,6), SAVE, SELECT, SETMSK, SUB, TEMP
      DATA  ADD/50018/, AND/40001/, BNZ/50011/, BRANCH/50017/,
     & END/50030/, IN/140806/, NOT/141607/, OR/40002/, POP/50019/,
     & RELOPS/30001, 50011, 30002, 50012, 30003, 50013, 30004, 50014,
     & 30005, 50015, 30006, 50016/, SELECT/50026/, SETMSK/50020/,
     & SUB/50006/
C
C * * * * * * * * EXECUTABLE CODE * * * * * * * *
C
       OUTPNT = 0
 10    CONTINUE
       OUTPNT = OUTPNT + 1
       TRPROW = TRPROW + 1
C   IF THE TOKEN IS END DELIMITER THEN FINALIZE THE TRIPLE ARRAY
       IF (OUTPUT(OUTPNT).EQ.END) GO TO 400
C   END OF IF
C
C   IF THE TOKEN IS '.OR.' PLACE IT IN THE TRIPLE ARRAY
       IF (OUTPUT(OUTPNT).NE.OR) GO TO 30
          TRIPLE(TRPROW,1) = 50022
          GO TO 10
C   END OF IF
C
 30    CONTINUE
C   IF THE TOKEN IS '.AND.' PLACE IT IN THE TRIPLE ARRAY
       IF (OUTPUT(OUTPNT).NE.AND) GO TO 50
          TRIPLE(TRPROW,1) = 50021
```

```
                GO TO 10
C   END OF IF
C
 50    CONTINUE
C   IF THE TOKEN IS 'IN' PLACE 'IN' AND THE GROUP IDENTIFIER IN THE
C      TRIPLE ARRAY
       IF (OUTPUT(OUTPNT).NE.IN) GO TO 70
          TRIPLE(TRPROW,1) = 50023
          TRIPLE(TRPROW,3) = OUTPUT(OUTPNT + 1)
          OUTPNT = OUTPNT + 1
          GO TO 10
C   END OF IF
C
 70    CONTINUE
C   IF THE TOKEN IS 'NOT' PLACE 'NOT IN' AND THE GROUP IDENTIFIER IN
C      THE TRIPLE ARRAY
       IF (OUTPUT(OUTPNT).NE.NOT) GO TO 100
          TRIPLE(TRPROW,1) = 50024
          TRIPLE(TRPROW,3) = OUTPUT(OUTPNT + 2)
          OUTPNT = OUTPNT + 2
          GO TO 10
C   END OF IF
C
C   ANY TOKENS WHICH FILTER DOWN TO THIS POINT ARE RELATIONAL EXPRESSION
C      OPERANDS OF THE LOGICAL OPERATORS.  PLACE THE SUBTRACT OPERATOR
C      IN COLUMN ONE AND THE TWO VARIABLES OR CONSTANTS IN COLUMNS
C      TWO AND THREE OF THE TRIPLE ARRAY
100    TRIPLE(TRPROW,1) = SUB
       TRIPLE(TRPROW,2) = OUTPUT(OUTPNT)
       TRIPLE(TRPROW,3) = OUTPUT(OUTPNT + 2)
       TRPROW = TRPROW + 1
       OUTPNT = OUTPNT + 1
C
C   OBTAIN THE PROPER CODE FOR THE RELATIONAL OPERATOR
C      REPEAT
C         COMPARE INPUT TOKEN WITH RELATIONAL OPERATORS UNTIL MATCH
          DO 140 I = 1,6
140          IF (OUTPUT(OUTPNT).EQ.RELOPS(1,I)) GO TO 150
C      END OF REPEAT
C
150    CONTINUE
C   PLACE THE PROPER BRANCH CODE, BASED ON THE RELATIONAL OPERATOR,
C      IN COLUMN ONE OF THE NEXT TRIPLE ROW
       TRIPLE(TRPROW,1) = RELOPS(2,I)
C   PLACE 'POP' OPERATOR IN COLUMN TWO OF THE TRIPLE ARRAY
       TRIPLE(TRPROW,2) = POP
       TRIPLE(TRPROW,3) = TRPROW + 3
180    CONTINUE
       TRPROW = TRPROW + 1
C   PLACE 'ADD  0  1' IN TRIPLE ARRAY FOR TRUE CONDITION
       TRIPLE(TRPROW,1) = ADD
```

```
            TRIPLE(TRPROW,2) = 0
            TRIPLE(TRPROW,3) = 1
            TRPROW = TRPROW + 1
C    PLACE 'UNCONDITIONAL BRANCH' AND TRIPLE ADDRESS IN TRIPLE ARRAY
            TRIPLE(TRPROW,1) = BRANCH
            TRIPLE(TRPROW,3) = TRPROW + 2
            TRPROW = TRPROW + 1
C    PLACE 'ADD  0  0' IN TRIPLE ARRAY
            TRIPLE(TRPROW,1) = ADD
            TRIPLE(TRPROW,2) = TRIPLE(TRPROW,3) = 0
            OUTPNT = OUTPNT + 1
            GO TO 10
C
C    FINALIZE THE TRIPLE ARRAY FOR BOOLEAN EXPRESSIONS.  SETMSK WILL
C       CAUSE THE EXECUTION PHASE TO SET A FLAG ACCORDING TO THE
C       RESULTS OF A TRUE OR FALSE BOOLEAN EXPRESSION.
400         CONTINUE
            TRIPLE(TRPROW,1) = SETMSK
            TRIPLE(TRPROW,2) = POP
            TRIPLE(TRPROW,3) = SELECT
            TRPROW = TRPROW + 1
C
C    IF PRTLVL = 0 WRITE OUT THE ORDERED TRIPLES
            IF (PRTLVL.NE.0) GO TO 700
600         N = TRPROW
            DO 550 TRPROW = 1,N
550            WRITE (6,510) (TRIPLE(TRPROW,J), J = 1, 3)
510            FORMAT (' ', T10, I7, T25, I7, T40, I7)
700         RETURN
            END
```

REFERENCES

1. Arden, Bruce W., Galler, Bernard A., and Graham, Robert M., "An Algorithm for Translating Boolean Expressions," Journal of the Association for Computing Machinery, 222-239, Volume 9, Number 2, April 1962.

2. Department of Defense, Task Analysis CODAP Executive's Overview Guide.

3. Gries, David, Compiler Construction for Digital Computers, John Wiley & Sons, Inc., New York, 1971.

4. Manning, Rocky, "The Design and Implementation of an Interpreter for a Data Management System," [illegible] Research Report, Department of Industrial Engineering, Texas A&M University, 197[illegible].

5. Occupational Research Program, CODAP User's Guide, (will not be completed until approximately March 19[illegible]).

6. Rosen, Saul, Programming Systems and Languages, McGraw-Hill, New York, 1967.

7. SAS User's Guide, SAS Institute Inc, Raleigh, North Carolina, 1979.

DATE
FILMED